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This report contains the results of the Investments in Avionics and Missiles Software and Software Technology Workshop held on May 31 and June 1, 1995 at the Software Productivity Consortium. The workshop convened a group of government, industry, and academic experts in the avionics and missiles domains. The objectives of the workshop were to elicit software technology challenges and identify potential investment opportunities.

The workshop participants were divided into five groups, three groups focused on the avionics domain and two groups focused on the missiles domain. Each workshop participant completed several worksheets reflecting their views on the challenges and investment opportunities in their group's domain. This report contains the worksheets completed by the workshop participants.

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CONTENTS

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EXECUTIVE SUMMARY

This document describes the results of the avionics and missiles workshop held on May 31 and June 1, 1995 for the Advanced Research Projects Agency/Software and Intelligent Systems Technology Office (ARPA/SISTO). This workshop was part of the Software Technology Challenges Profiles (STCP) project. The purpose of the STCP project is to identify current software technology challenges and potential benefits of investing in research into these challenge areas. A series of domain-specific workshops attended by experts from industry, government, and academia is being held to assist in the identification of software technology challenges and possible corrective actions. The purpose of the workshop on May 31 and June 1 was to investigate these challenges for the domains of avionics and missiles.

The workshop approach identified several important challenge areas in the avionics and missiles domains. The following is a partial list of software technology challenge areas that were identified as a result of analysis of the workshop data that is contained in this report.

- **Pilot and Crew Workload.** Pilot and crew workload is becoming excessive, inhibiting reaction times during conflict.

- **Unpredictable Development.** Missile development efforts cannot be accurately predicted due to an inability to evaluate requirements and design implications. This lack of predictability leads to schedule delays, unexpected costs, and procurement cancellations.

- **Uncontrollable Development.** Major avionics systems cannot be sufficiently controlled due to rapid hardware and software advances, leading to ongoing requirements, design, and capability volatility.

- **Hidden Capability Limits in Legacy Systems.** Attempts to evolve legacy systems are often costly and highly problematic due to unexpected limitations or constraints inherited from earlier versions.

- **Massive System Rework for Nominal Improvement.** Due to extremely tight coupling between hardware and software, small capability increases often require major costly rework.

- **Subsystem Success/Full-System Failure.** Subsystems that work in isolation often fail to work together, leading to schedule delays during the latest phases of a program.

- **Excessive Test/Certification.** Complex weapons systems, when updated, are subject to test and certification efforts wholly disproportionate to the magnitude of the update.

- **Fragile Technology in Hostile Environments.** As subsystems are increasingly depended upon to provide critical capabilities, loss of subsystems must be managed to ensure graceful—as opposed to catastrophic—loss of performance.

- **Immature and Unusable Leading Edge Technologies.** Although the research community has developed and demonstrated extremely promising technology, the technology typically lacks the robustness necessary for industry application.

1. INTRODUCTION

1.1 OVERVIEW

This document contains the results of the Investments in Avionics and Missiles Software and Software Technology Workshop held on May 31 and June 1, 1995 at the Software Productivity Consortium (the Consortium) for the Advanced Research Projects Agency/Software and Intelligent Systems Technology Office (ARPA/SISTO). This introduction provides general information on the Software Technology Challenges Profiles (STCP) project, more specific information about the workshop, and a description of how the reminder of the document is organized.

1.2 BACKGROUND

One objective of the STCP project is to assist ARPA/SISTO in identifying current software technology challenges. To facilitate identification of challenge areas and analysis of possible corrective actions, a series of workshops is being held so that industry, government, and academia can share their insights and experiences with ARPA/SISTO. To maintain focus, the workshop format is designed to be limited to specific domains in which software and software technologies play a significant role. To help ensure that the workshops are productive, a structured process was developed to help working groups express individual views and work together to reach consensus on the challenge areas and associated corrective actions.

The objectives of the ARPA Avionics and Missiles Workshop were to elicit software technology challenges and identify potential investment opportunities. To accomplish these objectives, the workshop convened a group of government, industry, and academic experts to participate in this 2-day workshop focused on the avionics and missiles domains.

1.3 THE WORKSHOP PROCESS

The workshop consisted of approximately 40 senior-level experts split fairly evenly between the software avionics and missiles domains. These individuals were invited because of their knowledge and expertise in the particular domains and because, as a group, they covered a wide range of the functional areas associated with the domains. Specifically, the functional areas for the avionics domain were mission sensors, flight control, flight station, navigation, communications, electronic warfare, and weapons (interfaces). The functional areas for the missiles domain were sensors/seekers, flight control, navigation, communications, electronic warfare, and warhead control.

The workshop began with plenary briefings that provided an overview of the workshop along with various presentations by ARPA and the Joint Advanced Strike Technology (JAST) program office.

Then, the workshop attendees were divided into five groups (of approximately seven persons each). Individuals were assigned to specific working groups based on their expertise in the functional areas to ensure as wide a coverage of the functional areas as possible in each group. This approach prevents any groups from overemphasizing any particular functional area at the expense of others. Three of the groups were dedicated to avionics, while the other two groups were focused on missiles. Some of the avionics and missiles groups started their work from scratch, whereas other groups were provided with data gathered from other sources, such as a prior avionics planning meeting held in April 1995.

Over the 2-day workshop, each group participated in seven working (i.e., breakout) sessions. Each session started with each group member drafting individual statements on a session worksheet. Each member then shared their opinions with the group. This was followed by open discussions and consensus on what the group would present to the entire workshop. At the end of each day, the workshop attendees reconvened to brief their group's results for the day's sessions. The seven working sessions were focused in the following areas:

- **Problems/Challenges: Opening Statements.** The purpose of this breakout session was to identify primary software technology challenges and to focus on problem areas. Data was obtained from both the individuals and the group in this session and was recorded on Worksheets #1 and #2, respectively.

- **Major Challenges: Cause-Effect Analysis.** The purpose of this breakout session was to outline any cause-effect relationships that exist among the major challenges. Data was obtained from both the individuals and the group in this session and was recorded on Worksheets #3 and #4, respectively.

- **Major Challenges: Feasibility Analysis.** The purpose of this breakout session was to outline the feasibility of addressing the major challenges in terms of level of effort, likelihood of success, and probable benefits. Data was obtained from both the individuals and the group in this session and was recorded on Worksheets #5 and #6, respectively.

- **Problems/Challenges: Closing Statement.** The purpose of this breakout session was to revisit the major challenges based on what was discussed in the previous breakout sessions. Only data from individuals was obtained in this session and was recorded on Worksheet #7.

- **Investment Opportunities: Opening Statement.** The purpose of this breakout session was to describe the best investment opportunities for ARPA/SISTO with regard to addressing the challenges elaborated in previous breakout sessions. Data was obtained from both the individuals and the group in this session and was recorded on Worksheets #8 and #9, respectively.

- **Draft Investment Model of $100 Million.** The purpose of this breakout session was to describe an investment model of how a hypothetical $100 million budget should be invested to address the challenges elaborated in previous breakout sessions. This investment model was described in term of total dollars, dollars/year, and total years (assuming a potentially multiyear investment model). Data was obtained from both the individuals and the group in this session and was recorded on Worksheets #10 and #11, respectively.

- **Investment Opportunities: Closing Statement.** The purpose of this breakout session was to capture final thoughts regarding ARPA investment into the challenges given the entire content of the 2-day workshop. Only individual data was captured in this session and is reflected throughout this report as Worksheet #12.

1.4 ORGANIZATION

The remainder of this report contains a section corresponding to each of the five working groups. Data within each section is organized by the information gathered on the worksheets during the breakout sessions (i.e., Worksheets #1 through #12). The appendixes contain the presentations given during the plenary session.

The report contains the following sections and appendixes:

- **Section 1, Introduction.** This section provides background information on the workshop that produced the information contained in the report.
- **Section 2, Avionics Group 1 Data.** This section contains the worksheets completed by Group 1, which focused on avionics and started with a "clean slate." This group was provided with no prior data.
- **Section 3, Avionics Group 2 Data.** This section contains the worksheets completed by Group 2, which also focused on avionics but started with the minutes from the avionics planning meeting held in April 1995, entitled "Investment in Avionics Software and Software Technology Planning Meeting Report," version 01.00.03, May 1995.
- **Section 4, Avionics Group 3 Data.** This section contains the worksheets completed by Group 3, which also focused on avionics and started with attendee registration form responses to the question: "What do you feel is the major challenge in developing software-intensive avionics/missiles systems?"
- **Section 5, Missiles Group 4 Data.** This section contains the worksheets completed by Group 4, which focused on missiles and started with a "clean slate." This group was provided with no prior data.
- **Section 6, Missiles Group 5 Data.** This section contains the worksheets completed by Group 5, which also focused on missiles and started with attendee registration form responses to the question: "What do you feel is the major challenge in developing software-intensive avionics/missiles systems?"
- **Appendix A, Closing Group Presentations (Draft Slides).** This appendix contains slides of the final workshop presentations for each group. The slides are in draft form. The groups were not asked to create "final" form presentations at the workshop.
- **Appendix B, Challenges in Avionics and Missiles Software and Software Technology ARPA/SISTO Workshop briefing (R. Bechtold, the Consortium).** This appendix contains slides from the plenary sessions conducted by the Consortium.
- **Appendix C, ARPA SISTO briefing (M. Gersh, ARPA).** This appendix contains slides from the workshop introductory session conducted by ARPA/SISTO (program overview).
- **Appendix D, Evolutionary Design of Complex Systems briefing (Capt. J. Bartow, JAST/TM2).** This appendix contains slides from the workshop introductory session conducted by JAST.

- **Appendix E, Evolutionary Design of Complex Software (Dr. H. Shrobe, ARPA).** This appendix contains slides from the workshop introductory session conducted by ARPA/SISTO.

2. AVIONICS GROUP 1 DATA

2.1 OVERVIEW

This section contains the information collected from Group 1 during the working sessions. Group 1 focused on avionics problems and challenges and started with a "clean slate" (i.e., they were provided with no prior data). The information in this section is organized by the forms that the working group members completed.

2.2 PROBLEMS/CHALLENGES: OPENING STATEMENTS

2.2.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to write an opening statement on their views of the software problems and challenges in the avionics domain. The following are their opening statements.

Name: 1-A

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

1. Lack of properly architected systems [both legacy and new (because we do not know how to do it)] compound evolution/maintenance of systems. Generally very inflexible.
2. Typically cannot exploit emerging hardware technologies.
3. Cannot compete with (/exploit) commercial practices because of DoD "culture" (both within government and industry).
4. Cannot (do not) capture design rationale (partially due to reluctance of engineers).
5. If DSP applications really constitute 60 to 70% of application, we have a long way to go to exploit state-of-the-art practices/environments.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 1-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

No cost feedback loop in early design

"I feel there is little, if any, cost feedback to software designers until very late in the development cycle. By that time, there is less opportunity to conduct design trades that would reduce life cycle costs."

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(Worksheet #1)

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Name: 1-C

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

In my opinion, it takes far too long to develop and test software. It is also an expensive task as well. We need to find ways to translate system requirements into a usable system in a quicker, less error-prone manner. We spend a lot of time testing because we do not trust the requirements translation process and/or because we do not understand the complexity of the system. If we could make that translation happen quicker and be more reliable, systems could be put together in a more rapid manner and be much more cost effective.

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Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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Name: 1-D

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Software is hard to maintain because design specifications and requirements become out of synch with implementations.

The solution is to obtain a tighter coupling between the description of the problem and the implementation of the solution.

- Higher-level programming languages
- Automatic conversion of specification to "programs" (but this is really high-level programming language)
- Automatic checking for consistency between specification and implementation
- Automatic links (e.g., browsers or hypertext links) between requirements descriptions and code.

In summary, we need to eliminate the potential for inconsistency between description of problems and working solutions. We need to encourage developers of specifications to be more thorough in their descriptions (e.g., include treatment of the 7 + 1 sins) and we need to provide more automatic support to connect requirements specifications to actual code.

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(Worksheet #1) Page 1 of 1

Name: 1-E

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Users/Designers/Developers cannot understand and/or reason about a software system (i.e., being developed, "evolving").

- difficult to understand impact of design decisions
- difficult to separate concerns (e.g., performance, functionality, reliability, etc.)
- difficult to separate software concern from hardware (processor) concerns (e.g., bit twiddling, memory overlays, etc.).

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Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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2.2.2 GROUP PERSPECTIVE

After discussion, Group 1 was asked to reach consensus on the problems and challenges by voting. The following are their group results.

Group 1

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes		Problem Number
(14)	Design Support Tools (adequate) • Support multiple views (including cost) • Support simulation and modeling (including cost) • "Open"	1.
(7)	Rapid (Engineering) prototyping (to refine requirements)	10.
(6)	DoD Culture • Acquisition process • Standards • Innovation not encouraged (opportunity: reward technology transfer and commercial practices within DoD	2.
(5)	Specifications/requirements get out of synch with implementations	4.
(4)	Inflexible software/systems architectures	5.
(4)	Layered views for design and development (layer for each "sin") (systematic introduction)	11.

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Please print your name on each page so that information can be properly organized.

(Worksheet #2) Page 1 of 2

Group 1

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes		Problem Number
(3)	One-way (e.g., top-down) methodologies do not match the current practices (evolutionary, iterative)	6.
(3)	Lack of early indicator metrics	8.
(3)	Lack of support (methodologies, tools) for composition/integration	9.
(1)	Cannot exploit new technologies (because software is not portable)	3.
	<Deleted>	7.

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(Worksheet #2)

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2.3 MAJOR CHALLENGES: CAUSE-EFFECT ANALYSIS

2.3.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to describe their views of the cause-effect relationships that exist among the major problems and challenges. The following are their responses.

Name: 1-A

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

1. Requirements traceability, rapid prototyping capabilities and more precise specifications could be a side effect of a sophisticated, integrated set of automated design tools.

2. Emerging hardware technologies could be utilized if adequate architectures were developed and minimal standards adhered to.

<u>Information Only</u>

3. The current ROI per software engineer in the commercial sector is as much as five times that experienced in the defense industry. Changing the culture in both the DoD and defense industries could make us much more competitive/productive.

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(Worksheet #3)

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Name: 1-B

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Because there is a lack of adequate, integrated, and "open" design support tools which allow multiple views of a system and simulation and modeling, software systems development is slow, disjointed, inflexible, not portable, and high cost.

The DoD Systems Acquisition culture must change to encourage innovation, use of commercial practices, technology transfer, and "open systems." Project managers should be incentivized to "make the right decisions" for the sake of the system and its life cycle costs.

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Name: 1-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

The major discussion in our group was not with problems in the application areas, but with problems in the design and development of avionics/missile software in general. Primarily, in that we are stuck with old systems that cannot easily accept new technologies. We also do not have appropriate methodologies for properly defining and modeling systems or the underlying tools to support such an effort. The result is we still take years to develop software and it continues to be expensive to do so.

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Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 1-D

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

The reason we do not have better (more adequate) design tools is:

1. Deciding what tool support is appropriate is a difficult problem (requires experimentation)
2. Requires standards for specification and programming languages, none of which exist currently.
3. This is a large and complicated system, even if we knew what we wanted to implement.

Similar problems impede the development of rapid prototyping environments: what standard notation should be used? Also, how do we represent the seven sins in prototype code? To reduce inconsistency between specification and implementation, we need to:

1. Eliminate the distinction between specification and code. Use a high-level language for specifications and expect automatic translation. Represent <u>all</u> requirements in the high-level code.

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Name: 1-E

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

---

(5) Inflexible Software Architecture ⟹ (3) Cannot Exploit New Technologies

⇑

(Lack of) Design Support Tools (1)

⇓

Lack of Early Indicators (8)

Rapid Engineering (10) ⇙ Negatively Influences — DoD Culture (2)

⇓

(11) Layered Views of Design

⇓

Early Indicators (-3) ⇐ Design Support Tools (Adequate) (1)

⇓

Flexible Architecture (-5)

⇓

Can Exploit New Technology (-3)

⇓

Specifications/Requirement in Sync with Code (-4)

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Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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2.3.2 GROUP PERSPECTIVE

After discussion, Group 1 was asked to reach consensus on the cause-effect relationships by voting. The following are their group results.

Group 1

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).

1. Research on 9, 10, and 11 would support 8 (and this would iterate).
2. The reason we do so much testing is because our current requirements methodologies are ad hoc (unreliable).
3. Implementation decisions may affect subsequent requirements impact analysis.

(No vote)

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Please print your name on each page so that information can be properly organized.

(Worksheet #4)

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2.4 MAJOR CHALLENGES: FEASIBILITY ANALYSIS

2.4.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to describe their views on the feasibility of addressing the major problems and challenges. The following are their responses.

Name: 1-A

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
A – The concept of ARPA providing "seed" money for selected technologies on selected programs could be a big first step in breaking down the inefficient DoD culture which stifles innovation.	3	4	5
B – The development of a comprehensive software design automation toolset supporting multiple views could reduce cycle time and increase productivity tremendously.	7	4	7
C – Requirements prototyping should be a fallout of B. Requirements based on automatic test/generation should follow.	3	7	7
D – Implementation impact analysis and iteration should be a fallout from B.			

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 1-B

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
A – ARPA seed money.	4	4	5
B – Machine parsable notation for requirements .	5	3	7
C – Requirements prototyping.	4	4	7
D – Feedback from implementation decisions to requirements.	3	5	7
E – Early indicate metrics.	3	4	5
F – Automated test generation tools.	5	4	4
G – Requirement notation for tradeoffs.	5	4	7
H – High-level, real-time programming language implementation techniques.	7	4	5

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(Worksheet #5)

Page 1 of 1

Name: 1-C

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

Challenge	Level of Effort	Likelihood of Success	Probable Benefit
Development of automated test generation given a rigorous requirements definition at the software level and system level.	5	5	7
Development of automated estimations for timing, sizing, cost, schedule.	4	5	5
	3	5	5
A – ARPA seed money	7	4	5
B – Machine parsable notation for requirements	7	4	5
C – Requirements prototyping	4	5	5
D – Feedback from implementation decisions to requirements			

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 1-D

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
A – ARPA seed money.	3	4	4
B – Machine parsable notation for describing all requirements (to serve as basis for analysis, simulation and modeling, design automation, and code generation).	7	3	7
C – Direct requirements prototyping.	4	4	5
D – Feedback to requirements management from implementation phases.	4	5	4
Tools to specifically support real-time analysis and development.	4	4	5
Programming notations to describe cost-effective high-performance real-time systems.	4	4	4
High-level, real-time programming language implementation techniques (e.g., garbage collection). Tools to analyze, simulate, model, translate the notation of B.	4	4	5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 1-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

Challenge	Level of Effort	Likelihood of Success	Probable Benefit
A – ARPA to provided seed money to pilot specific innovations within targeted DoD programs.	3	4	5
B – Machine parsable notation for describing all requirements (cost, performance, function as separate views) could serve as basis for analysis simulation and modeling, design automation tools, ultimately leading to code generation.	7	4	7
C – Requirements prototyping – Evolution of requirements – Visualize multiple views – Supports standard product and process	7	4	7
D – Support feedback from implementation decisions to requirement management.	5	4	4
E – Early Indicate Metrics	5	4	5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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2.4.2 GROUP PERSPECTIVE

After discussion, Group 1 was asked to reach consensus on the feasibility analysis by voting. The following are their group results.

Group 1

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

Votes		Level of Effort	Likelihood of Success	Probable Benefit
(13)	B. Machine parsable notation for describing all requirements (cost, functionality, performance as separate views) (could serve as a basis for analysis, simulation and modeling, design automation tools, ultimately leading to code generation).	7	4	7
(12)	C. Requirements prototyping allowing: • Evolution of requirements. • Ability to visualize multiple views. • Supports standardized products and processes (both software and system engineering).	5	4	6

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Please print your name on each page so that information can be properly organized.

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Group 1

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

Votes		Challenge	Level of Effort	Likelihood of Success	Probable Benefit
(7)	A.	ARPA to provide seed money to pilot specific innovations within targeted DoD programs.	3	4	5
(4)	D.	Support feedback from implementation decisions to requirements management.			
(4)	E.	Map to correct requirements to early indicators.			
(4)	G.	Requirements notation to allow tradeoffs between requirements (e.g., cost versus reliability versus functionality) <G. is really specialization of C.>			
(3)	F.	Development of automated test generation tools (based on requirements) <F. is really specialization of B.>			
(3)	H.	High-level, real-time programming language implementation techniques (e.g., real-time garbage collection).			

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Please print your name on each page so that information can be properly organized.

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2.5 PROBLEMS/CHALLENGES: CLOSING STATEMENTS

2.5.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to revisit their opening statements on the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 1-A

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

---

1. Creating a comprehensive software "design automation toolset," encompassing requirements modeling, design modeling, rapid prototyping, visualization of multiple views, mode-based test case generation, etc.

2. Changing the DoD procurement-oriented infrastructure to be one as competitive and cost-effective as the commercial sector.

3. Changing avionics software/system architectures to be flexible and encompass open system standards (for vendor interoperability).

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 1-B

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

The software development environment could greatly benefit from a change in DoD acquisition culture and the development of specialized requirements notation which would serve the subsequent development of tools for systems analysis, simulation and modeling, design and code automation, all of which would be used in an ESP or rapid prototyping/rapid engineering development process to better iterate and converge to an optimum, affordable system.

ARPA could speed this process by providing seed money to specific pilot programs to develop the above-mentioned tools and process methodologies.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-C

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

A lot of what we focused on today dealt with requirements. It was pretty much felt that the lack of well-defined requirements is a root cause of many of the problems that are encountered in software development. We felt that if we could formalize requirements definition, that would lead to ways to automate code and test generation. It would also allow for a more rapid response to user requests. In the end, this would lead to systems that are more reliable, more maintainable and more responsive to the needs of the user and, thus, more economical. This is consistent with what I considered to be the major software challenge at the start of today's session.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7) Page 1 of 1

Name: 1-D

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

A standard requirements language would be very useful for helping software designers and engineers to communicate and to track their evolutionary development efforts. If automatic translation from requirements to implementation can be provided, potential inconsistency between specification and implementation can be eliminated. If the requirements language (and supporting tools) supports multiple views, this notation would facilitate the management of system complexity (functional issues can be isolated from memory requirements and so forth). This seems to be the "best" recommended technology evolving from our group. But additional alternative technologies should probably be pursued with a lower level of commitment.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-E

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

The most needed software initiative is the ability to reason about (not just describe!) an evolving software artifact. Opportunities exist for:

(A) Incentivize select DoD program to field innovation technology by ARPA seed money for pilot-specific innovations.

(B) Defining machine processable notation to describe all requirements and incrementally add and reason about each view (cost, schedule, function, performance).

(C) Developing requirements prototype tools that facilitate the incremental evolution (with each view) of requirements and the delivered product with multiple views.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

2.5.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

2.6 INVESTMENT OPPORTUNITIES: OPENING STATEMENTS

2.6.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to describe their views on the best investment opportunities for ARPA/SISTO with regard to the major problems and challenges. The following are their responses.

Name: 1-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. ARPA should invest in a program "like RASSP" for software to develop tools and models which can "talk" to each other and can speed up the validation and evolution of system requirements. The tools or models developed under this program should:

a. Facilitate unambiguous representation of requirements

b. Capture multiple views of the system (functional, performance, cost, logistical, etc.)

c. Facilitate flowdown/feedback to design web

d. Support composition and reuse of requirements

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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Name: 1-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

On the F/A-18, it currently takes about three years for a new user requirement to make it into a fleet aircraft. Captain Bartow stated that it is going to take about seven years to do JAST software with only a five-year EMD period. All of this stems from the fact that requirements are ill-defined. It takes implementors a long time to figure out what the requirements are and what they mean. Then we spend a lot of time testing to make sure that we did understand the requirements correctly. ARPA/SISTO should invest in a method/scheme for better characterizing system requirements. This would lead to reduced development time, less rework, and less test time, providing for a faster response to user needs, systems that meet requirements the first time and reduced system cost.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Captain Bartow's observation:

"We don't learn from our mistakes"– Lessons learned on one project (e.g., autopilot between multiple way points) are forgotten, and must be rediscovered on the next project.

- This is expensive because the impact of the error is discovered late, and retrofitting the correction may have global impact.
- If the requirements descriptions of previous systems had been kept up to date, and automatic support for composition of requirements from previous systems were available, these problems could be avoided.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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2.6.2 GROUP PERSPECTIVE

No group perspective on the opening statements for investment opportunities was documented by Group 1.

2.7 DRAFT INVESTMENT MODEL OF $100 MILLION

2.7.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to describe their views of how a hypothetical $100 million budget should be invested to address the problems and challenges. The following are their responses.

Name: 1-A

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

		Feasibility	Total $	$/Year	Total Years
A	Avionics Requirements Representation	5/7	$32M	$8K	4
B.	Integration of multiple views	4/7	36M	6K	6
C.	Prototype methodology and tools based on A and B	5/7	32M	4K	8

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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Name: 1-B

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	PB	Feasibility	Total $	$/Year	Total Years
A. Avionics Requirements Representation	6	5	$30	$15	2
B. Integration of multiple views	7	6	50	15/25/10	3
C. Prototype methodology and tools based on A and B	5	5	20	10/10	2

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 1-C

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	LOS	PB	Total $	$/Year	Total Years
A. Avionics Requirements Representation	5	7	$30	$15	2
B. Integration of multiple views	4	5	40	13.3	3
C. Prototype methodology and tools based on A and B	4	5	30	7.5	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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Name: 1-D

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	SMCC	Payoff	Total $	$/Year	Total Years
A. Avionics Requirements Representation	6	5	$10	$5	2
B. Integration of multiple views	6	5	10	5	2
C. Prototype methodology and tools based on A and B	5	6	80	20	4 (start after 2 years)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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Name: 1-E

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
A. Avionics Requirements Representation	$10M	$10M	1
B. Integration of multiple views	40M	20M	2
C. Prototype methodology and tools based on A and B	50M	17M	3

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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2.7.2 GROUP PERSPECTIVE

No group perspective on the investment model was documented by Group 1.

2.8 INVESTMENT OPPORTUNITIES: CLOSING STATEMENTS

2.8.1 INDIVIDUAL PERSPECTIVE

Each member of Group 1 was asked to revisit their opening statements on the investment opportunities to address the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their responses.

Name: 1-A

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

The lack of automated design tools for software paralleling the capabilities currently available for hardware has left us far behind the power curve. Existence of such tools (for requirements and design modeling, test case generation, etc.) can help make software engineering more of a science than art.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 1-B

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

I believe if ARPA invests in the three areas identified by Group 1, a 30 to 40% improvement or reduction in time/cost will easily result.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-C

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

I think if ARPA/SISTO where to invest as we indicated in our group, it would go a long way to solving many of the problems that we have. I do not really have anything to add to our group consensus.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-D

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

Maintenance and development of evolving requirements and design "documents" and coordination of this effort with evolving implementations are the major problems that must be addressed during the coming years.

Of high potential benefit would be support for a standard high-level notation that would serve the needs of requirements authors, designers, and ultimately developers. Support for multiple views assists in managing complexity.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 1-E

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

ARPA/SISTO should invest in an avionics-focused agile requirements animation technology development effort. Why?

- Meet user needs by "show and tell" rapid prototyping in problem space
- Facilitate "seamless" translation to design support tools
- Address the current disjoint nature of requirements versus design versus code

Allocate $100M to do technology development over 8 to 10 years.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

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2.8.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

3. AVIONICS GROUP 2 DATA

3.1 OVERVIEW

This section contains the information collected from Group 2 during the working sessions. Group 2 focused on avionics problems and challenges and started with the minutes from the avionics planning meeting held in April 1995, entitled "Investment in Avionics Software and Software Technology Planning Meeting Report," version 01.00.03, May 1995. The information in this section is organized by the forms that the working group members completed.

3.2 PROBLEMS/CHALLENGES: OPENING STATEMENTS

3.2.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to write an opening statement on their views of the software problems and challenges in the avionics domain. The following are their opening statements.

Name: 2-A

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

1. It is often too costly, lengthy, and error-prone to develop and evolve the software elements of avionics systems.
2. Communication between system developers and end users is extremely difficult, often yielding suboptimal solutions.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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Name: 2-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

---

1. Software is not as peculiar as we think it is. Most of what Howie Shrobe laid out is valid and must be addressed at the system level with software items as players in resource teams that fill system roles.

2. Performance regimes are better buckets for hardware/software team solution strategies than are mission domains. Hard to sell; requires capital mentality—market formation as a risky thing meriting profit. Gives rise to business-sensitive secrecy.

3. Program Management (contracts, etc.). Reward systems do more to inhibit software plasticity than do SEE technology factors. Software engineering thinks in terms of a performance/plasticity tradeoff or balance.

   My canard has been that as long as the people who approve budgets are re-elected every two years, it is impossible to mobilize the reward system for an investment in long-term concerns such as software plasticity.

Notes:

1. Already the form instructions treat problems versus solutions as a static, binary distinction. This is a bug we must expunge if we are going to "conquer rationale management" and restore systems management discipline to software activities. Problem/solution is a relationship type in a multistage food chain, not classes of different things.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 2-C

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

- Cost-effective adaptation of systems to changing needs
- Excessive costs of testing and certification
- Legacy systems: how to bring them forward into new reuse/evolvability frameworks

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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Name: 2-D

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Need to get the cost of software development down for sensor system applications (radar, EW). System upgrades (hardware and increased functionality) and maintenance is a major component of a system that is in the field for 50 years. Software development/maintenance for sensor systems requires highly-trained, experienced (and expensive) developers. Approaches need to be found for developing and testing software that requires less handcrafting by individual experts.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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Name: 2-E

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Background – Existing avionics systems have a life of 20 to 30 years. Future systems can be expected to have even longer lives. Each time requirements change, refinements made, enhancements included, etc., major changes are required to the entire systems even when other functionality is not changed. This makes system changes unaffordable. Local changes impact overall system.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

3.2.2 GROUP PERSPECTIVE

After discussion, Group 2 was asked to reach consensus on the problems and challenges by voting. The following are their group results.

Group 2

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes		Problem
(13)	P1:	How to bring legacy systems into new reuse/evolvability paradigms
(10)	P2:	Excessive cost of test and certification
(8)	P3:	Developer – user communication
(7)	P4:	High error rates in software avionics: unbounded costs for certain classes of errors
(7)	P5:	Localized changes end up costing 0 (size of system)
(2)	P6:	How to formulate useful/sturdy abstractions in specific domains (e.g., radar/sensor)
(2)	P7:	Procurement processes and budgets militate against evolvable software
(1)	P8:	Software development is inadequately integrated with system engineering
(0)	P9:	Software development is dependent on expensive people with unique skills

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #2)

3.3 MAJOR CHALLENGES: CAUSE-EFFECT ANALYSIS

3.3.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to describe their views of the cause-effect relationships that exist among the major problems and challenges. The following are their responses.

Name: 2-A

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

P_1 – C_1 – Ineffective documentation

– C_2 – Lack of clear system architectures

– C_3 – Use of static versus "active" language for development

– C_4 – Development discipline issues

– $C_5 = P_2$ $C_6 = P_5$ $C_7 = P_3$ $C_8 = P_7$ $C_9 = P_6$

P_2 – $C_1 = P_7$

– C_2 – Certification does not take advantage of development time test data to minimize costs

– C_3 – Simplistic legislation and interpretation thereof

P_3 – $C_1 = P_7$

– C_2 – Lack of commonly understood domain-specific languages (natural)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3) Page 1 of 1

Name: 2-B

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

1. High cost of re-qualification caused by de facto, inadequately known couplings; leads cost of minor change to approach scale of total systems.
2. Lack of high-level knowledge of legacy systems follows from fact that none but very bottom-line, low-level methods are trusted for certification. [Abstractions viewed as overhead, prime cost.]
3. Yes, advances in Distributed Interaction Simulation (DIS) and Virtual Reality (VR) will help with developer-user communication.
4. In commercial endeavors, pooling customers to make markets is tied to risk and investment. It is not clear that multi-use modules will be achieved in military systems until the institutional vehicles are there to reward risk-taking as opposed to purely risk-averse behavior.
5. Abstraction relationships need to be both more flexible and more trustworthy. This is how one gets malleable architectures. System functions, software, and hardware are the subjects of coupled chains of abstractions.

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Please print your name on each page so that information can be properly organized.

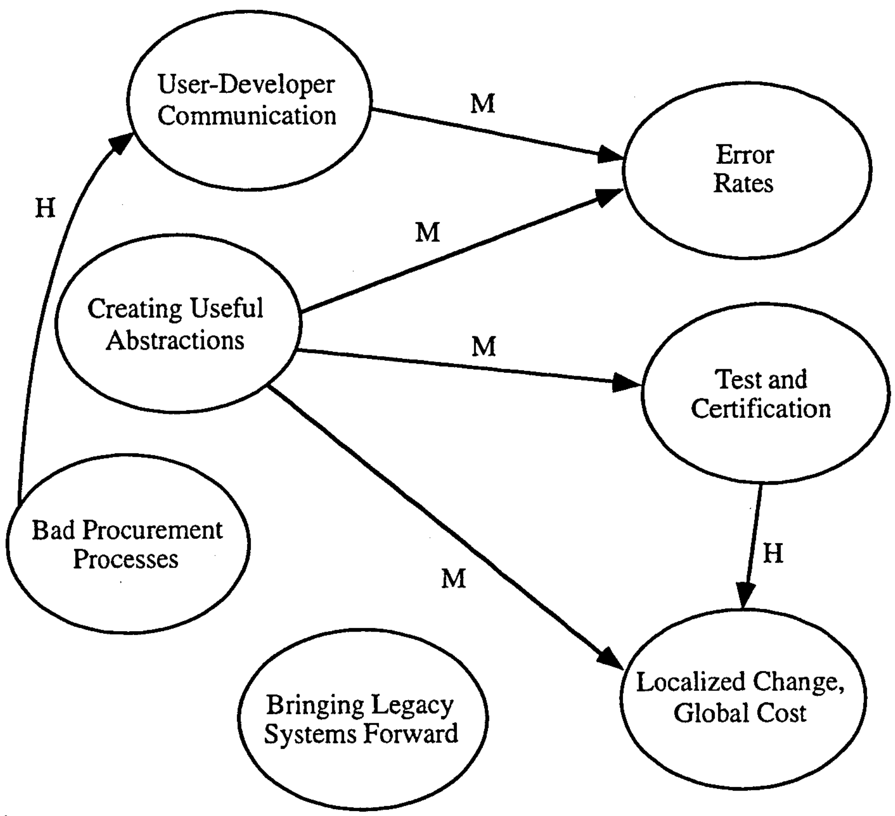
(Worksheet #3)

Page 1 of 1

Name: 2-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).



X→Y: X causes Y or contributes to Y

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 2

Name: 2-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Error Rates

1. Inadequate training
2. Inadequate program correctness/(informal) program proof technology
3. Inadequate system test technology

User/Developer Communication

1. Inadequate prototyping
2. Technical people frame terms of discussion; maybe domain experts should

Test and Certification Cost

1. Inadequate system component
2. Isolation for distributed RT systems

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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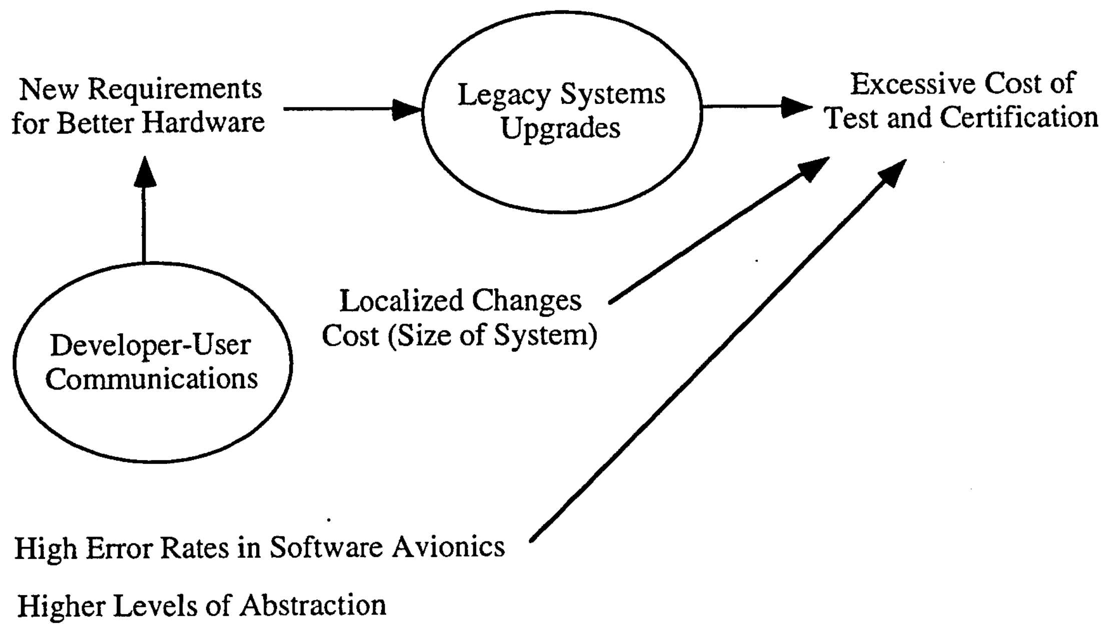
Name: 2-D

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).



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Please print your name on each page so that information can be properly organized.

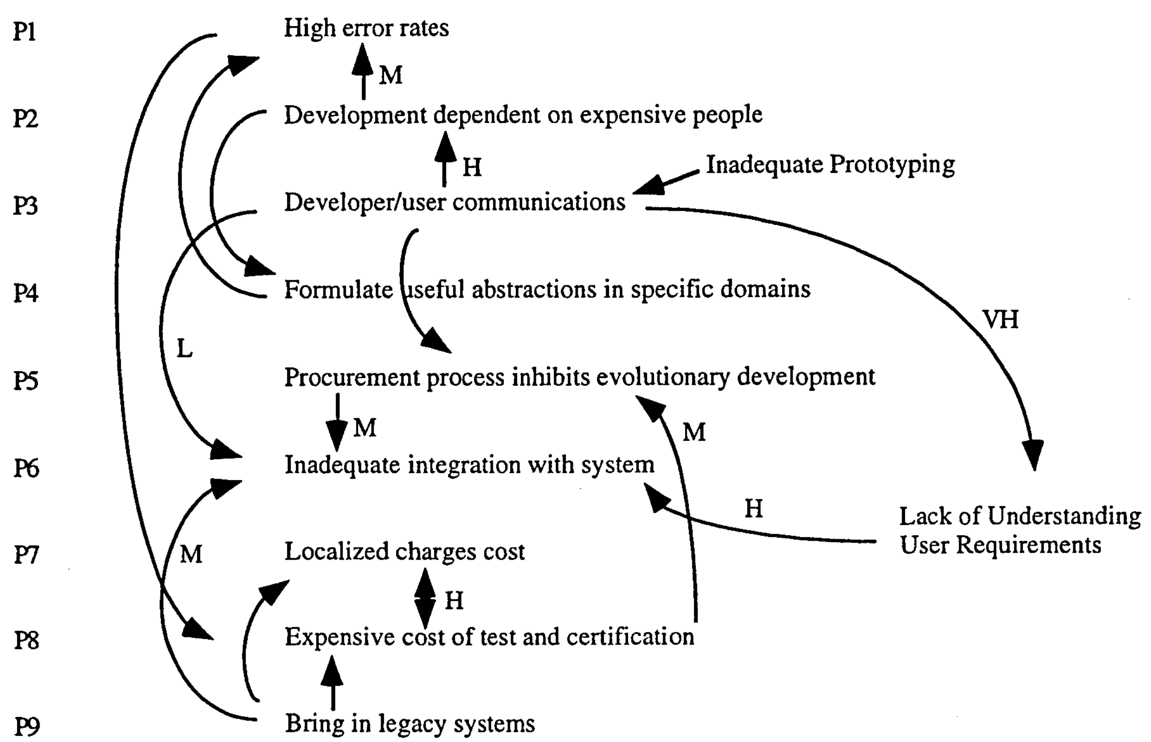
(Worksheet #3)

Page 1 of 1

Name: 2-E

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).



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Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

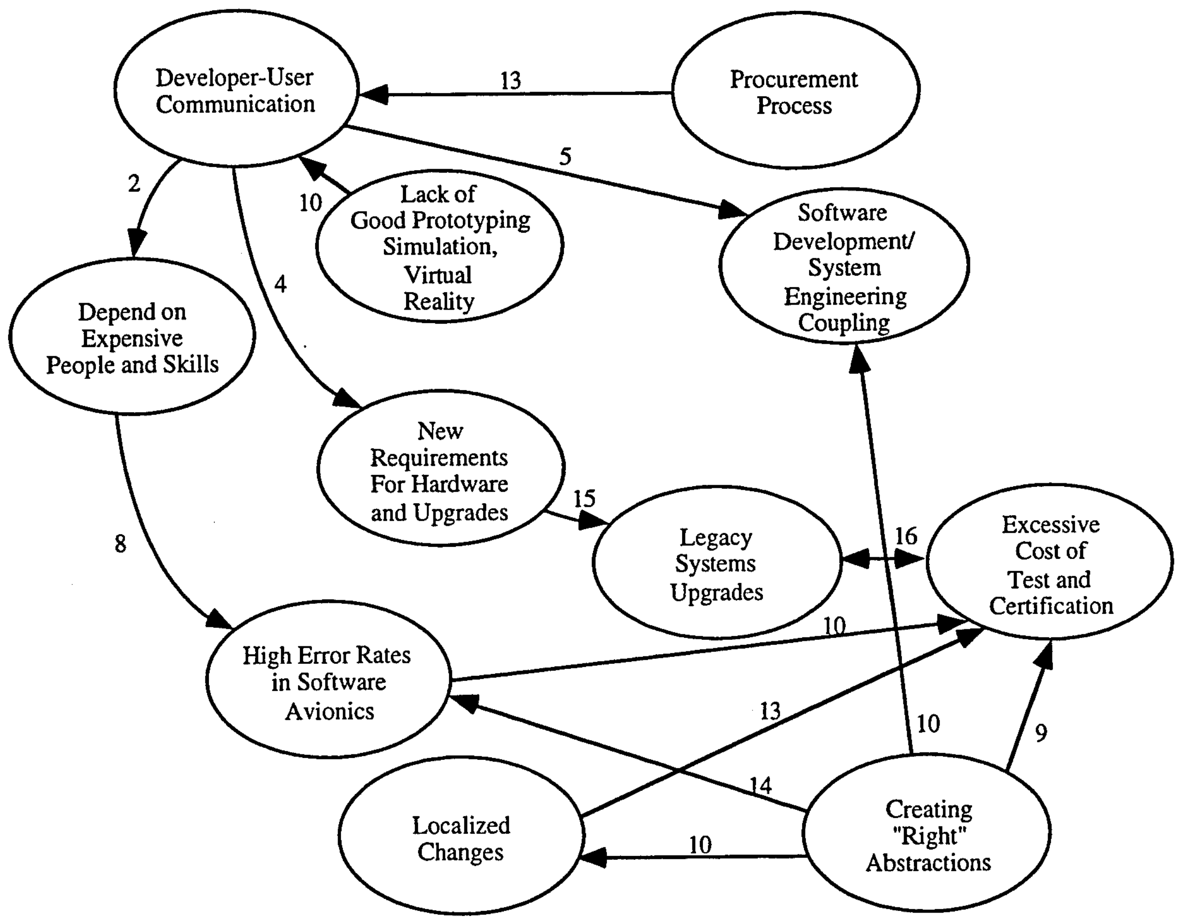
3.3.2 GROUP PERSPECTIVE

After discussion, Group 2 was asked to reach consensus on the cause-effect relationships by voting. The following are their group results.

Group 2

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).



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Please print your name on each page so that information can be properly organized.

(Worksheet #4) Page 1 of 1

3.4 MAJOR CHALLENGES: FEASIBILITY ANALYSIS

3.4.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to describe their views on the feasibility of addressing the major problems and challenges. The following are their responses.

Name: 2-A

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Legacy systems	7	4	7
2.	Test/certification cost	3	5	5
3.	Developer-users communication	5	4	7
4.	High error rates	3	7	7
5.	Cost of local changes	3	4	5
6.	Sturdy abstractions	4	4	5
7.	Procurement processes	4	4	7
8.	Software/system engineering initiative	3	5	4
9.	Expensive people	7	1	1

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

Name: 2-B

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Challenge	Level of Effort	Likelihood of Success	Probable Benefit
1.	Legacy systems	5	4	5
2.	Cost of test and certification	5	5	4
3.	Developer-user communication	4	4	5
4.	High error rates versus perceived cost of failure	4	5	4
5.	Local changes cost 0 (system)	4	5	5
6.	How formulate useful/sturdy abstractions	4	4	5
7.	Procurement processes (budgets mitigate against evolvable software)	3	3	5
8.	Software inadequately integrated with system engineering	4	5	4
9.	Software development dependent on expensive people with unique skills	3	3	3

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

Name: 2-C

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
Legacy Migration	4	5	7
Emulation, wrapper technologies, unobtrusive address space monitoring are feasible; payoff very high due to retaining value invested in current/legacy systems			
Test/certification	5	7/4	6
Benefit high since this is a big cost driver			
Likelihood of success: high for test, medium/low for certification (full certification; some forms of certification earlier in life cycle could be feasible and have medium payoff)			
Communication	4	5	5
Error rates	2	5	5
• Clean room?			
Local charges/global costs	7	3	7
Useful abstractions	4	6	6

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

Name: 2-D

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Legacy systems	3	4	5
2.	Cost of test and certification	5	5	7
3.	Developer-users communication	3	5	3
4.	High error rates in software development	3	5	5
5.	Localized changes	3	5	5
6.	Abstractions for specific domains	5	5	5
7.	Procurement process	5	3	5
8.	Software development integrated with system engineering	4	5	4
9.	Expensive people with unique skills	5	3	4

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

Name: 2-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
Bring legacy systems into new/evolvability paradigms • Cannot afford to reinvent - must use as much of existing systems as feasible • New functionality must be added to meet user requirements • Technology obsolesce will force upgrade of existing legacy systems	4	5	5
Excessive cost of test and certification • Requires change of policy	3	4	7
Developer-user communication • Involve users early and define methodology for formal communications	4	5	5

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 2

Name: 2-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
High error rates in software avionics	3	3	4
• Error rates are a product of earlier initiatives			
Localized changes end up costing	4	4	4
How to formulate useful abstractions in specific domains	3	3	3
Procurement process	5	1	7
Software development integration			
Software development is dependent on expensive people.			

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 2 of 2

3.4.2 GROUP PERSPECTIVE

After discussion, Group 2 was asked to reach consensus on the feasibility analysis by voting. The following are their group results.

Group 2

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Legacy systems	4.6	4.4	5.8
2.	Cost of test and certification	4.2	4.8	5.8
3.	Developer-user communication	4.0	4.6	5.0
4.	High error rates in software development	3.0	5.0	5.0
5.	Localized changes	4.2	4.2	5.2
6.	Abstractions for specific domains	4.0	4.4	4.8
7.	Procurement process	4.25	2.75	6.0
8.	Software development integrated with systems engineering	3.67	5.0	4.0
9.	Expensive people with unique skills	5.0	2.3	2.7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #6)

Page 1 of 1

3.5 PROBLEMS/CHALLENGES: CLOSING STATEMENTS

3.5.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to revisit their opening statements on the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 2-A

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

1. New approaches to evolving, repairing and/or reengineering legacy systems.
2. Excessive cost of test/certification.
3. Developer/user communication.
4. Cost of latent software errors/failures in fielded systems.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 2-B

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

I believe that the vision Dr. Shrobe painted is the way to go, if you can communicate the possibilities to the participants. That takes unlearning what they now know. Unlearning is hard.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 2-C

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

Key problems:

1. Develop software tools and technology to support low-cost increment, functionality and performance upgrades.
2. Import existing/legacy systems into these new technology frameworks.
3. Localized changes often results in costs proportional to total system size.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 2-D

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

Hardware upgrades and functionality enhancements are part of any system that will be deployed for up to 50 years. Changes to avionics legacy systems is costly due to testing and certification processes. Even now programs like JAST are looking at reusing legacy systems by the year 2000+.

Issues to be addressed:

- Integrated avionics
- Situation Awareness
- Sensor fusion

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 2-E

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

---

1. Cost effective way to deal with legacy systems-reuse, enhancements, technology insertion. Cannot afford to reinvent.
2. Effective developer/user communications.
3. Reduced cost of testing and certification.
4. Isolate impacts of localized changes.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

3.5.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

3.6 INVESTMENT OPPORTUNITIES: OPENING STATEMENTS

3.6.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to describe their views on the best investment opportunities for ARPA/SISTO with regard to the major problems and challenges. The following are their responses.

Name: 2-A

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. What problem/challenge is being targeted?
   How to bring legacy systems into new reuse/evolvability paradigms
2. What is the hard issue?
   Lack of extant standards that has produced systems in a wide variety of forms/architectures and extensibilities.
3. Where have you experienced this issue?
   System maintenance on . . .
   Attempts to reuse existing software on . . . .
4. What was the impact?
   a. Many hours spent FINDING and REPAIRING defects
   b. Disappointment and extensive cost overruns
5. What might have reduced/mitigated the impact?
   - Domain specific standards, architectures, languages . . . had they been used to produce the systems under maintenance/evolution
   - Effective documentation
6. Where can ARPA/SISTO invest that will help?
   Standards, architectures, languages, documentation, software understanding, processes, wrappers, emulators, and reengineering methods
7. What programs might benefit?
   All airframes with software content - directly proportional to the amount of software and mission change.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8) Page 1 of 1

Name: 2-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. What problem? Bringing legacy systems into . . .

2a. What is hard? Architecture of old system exists. Is not documented (even nearly accurately and sufficiently). Excavating the necessary indicators and reconstructing the architectural principles is hard.

3a. Submarine software for which no source code survives (defer to others).

4a. Software unchanged-system goes obsolete.

2b. What is hard? Viewing the modification from as_was, and to_be architectural perspectives. People tend to want to lock into and internalize one view, tend to neglect neighbor views.

3b. Deep infrastructure projects (language tools).

4b. Some requirements languish and are never met.

5a. What might have mitigated.
   1. Robust software understanding (generalized disassembler) tools.
   2. Robust SEE that comprehends concurrent architectural views.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Page 1 of 2

Name: 2-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

5b. What might have mitigated.
1. IPT
2. OOA

6a. Where SISTO invest:
- Demonstrations of capturing as_is architectures onto very powerful/general foundations such as Knowledge Interchange Format (KIF).
- Demonstrations of Multiply Oriented Objects (MOO) (i.e., polymorphism) and SEE in avionics software context.
- Cost-share with system program on software change hosted in a process environment that survived the technology-integration-demo phase.

7. B-1, B-2, F-15, F-16 (but "I am not your best witness on this, Senator.")

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Page 2 of 2

Name: 2-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. What problem/challenge is being targeted?
   Bringing legacy systems forward into current and future reuse/evolvability frameworks.

2. What is the hard issue?
   Properly encapsulating existing/legacy code so that it integrates adequately into newer system architectures.

3. Where have you experienced this issue?
   Integration of old route planning software into a distributed simulation environment.

4. What was the impact?
   Six months was wasted. Eventually we threw out the old code and completely reimplemented the algorithms from scratch.

5. What might have reduced/mitigated the impact?
   Runtime subsystem interface layer; "semantically rich" software bus.

6. Where can ARPA/SISTO invest that will help?
   a. Technology and research ideas that support adaptation and evolvability of long-lived systems.

   b. Devise research ideas that enable current/legacy systems to be brought forward and used in evolvable systems.

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Page 1 of 2

Name: 2-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

7. What programs might benefit?
   B-2 conventional mission planning enhancements "research proposal:" crisp technology ideas.
   a. Automated reengineering tools that guarantee correctness of certain aspects of resulting code but also carry forth inferred design or incorporate reengineered design (factor out correctness issues: functionality, timing, security, etc.) Obtain guarantees of certain aspects correctness automatically.

   b. Wrapper/emulation/runtime toolbus technology; applicable when it is infeasible to immediately do an entire reengineering effort

   c. "Design rationale:" Investigate rich type systems in programming languages so that a well-typed program contains more design information (meta language programs are harder to get to compile clearly than C programs, but easier to get to run correctly, and easier to understand. Type information provides design insight).

   d. Devise techniques for trusted or safe systems to factor out system components and criteria, so that certification efforts can be directed and focused where they are needed as systems evolve; encapsulate volatile technology so that they can be incrementally changed, and system trust can be regained in a focused manner.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Page 2 of 2

Name: 2-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

1. Problem/challenge

   Maintenance/upgrades of legacy systems. Hardware upgrades driven by COTS processors with ever more powerful capabilities are occurring at a faster rate than new software can be developed. In many cases, it is too costly to rewrite the code and revalidate it.

2. Hard issues

   - Understanding current system and what impact a change might have
   - Timing perturbations with new changes
   - New errors introduced with each upgrade/modification

3. Experience

   F-15, B-2, F-18 need to upgrade their processors from 16-bit to 32-bit advanced processors. They are at the limit of their margin reserves (e.g., F-18 RUG).

4. Impact

   All solutions carry risk and are costly - 1 for 1 bug replacement).

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 2-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

5. Reduce/mitigate impact

   - Limit the scope/need for certification by having firewalls.
   - Capture design rationale so are aware of all impact.
   - Improve cost of test and certification.

6. Invest

   - Design Web.
   - Capability to capture design rationale easily.

7. F-15, B-2, F-18, F-22 eventually, JAST for using existing relevant software (e.g., OS with POSIX)

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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Name: 2-E

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Bring legacy systems into new reuse/evolvability paradigms (Examples)-

Add new functionality
Technology insertion
Changing user requirements

Hard Issue -

Contain the impact of a change, i.e., not impact the entire system that requires extensive retest and recertification.

Avoid the redesign of existing systems.

Integrate existing functions into new architecture.

Where experienced?

Upgrade to mission computer on number of platforms - F-18, F-14, V-22, SH-60B

What was impact?

Much of system software was redeveloped. Some applications were ported from existing systems.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 2-E

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What might have mitigated the impact?

Tools and processes to help analyze the characteristics of the elements being replaced and validate that the replacement item performs at least to same functionality and performance. Reengineering.

Where can ARPA/SISTO invest?

Tools and processes and demonstrate feasibility with a real system. Supplement funding of specific government labs and industry in trying to improve these areas.

What problems might benefit?

All platforms that plan upgrades to processing capability. F-18, F-15, F-16, E-3, F-22, etc.

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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3.6.2 GROUP PERSPECTIVE

After discussion, Group 2 was asked to reach consensus on the investment opportunities by voting. The following are their group results.

Group 2

Investment Opportunities: Opening Statement
Group Perspective

Please describe what the group considers to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

- Avionics <u>must</u> evolve:
  - Changing threat/mission
  - Changing concept-of-operation (e.g., RT intelligence information in cockpit)
- Avionics <u>will</u> evolve:
  - Processor upgrades
  - Sensor/peripheral changes
- E.G.
  - B2 inflight replanning
  - V22 mission processor upgrade
  - F18 radar processor upgrade

<u>Impact:</u>

- Expend lots of dollars
  - Redevelopment
  - Testing and certification
- Bathtub curve
  - Resulting from injection of new "deeper" errors (e.g., 1:1 bug replacement)

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Please print your name on each page so that information can be properly organized.

(Worksheet #9)

Page 1 of 2

Group 2

Investment Opportunities: Opening Statement
Group Perspective

Please describe what the group considers to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Examples of what to do?

- System understanding tools
  - Logic
  - Timing
  - Performance
  - Layout/data structure
- Standardization
  - Operating systems
  - Databases
  - Displays
  - Other common services
- Prototype architecture workstations
- Explore ways of attacking the cost-of-testing/certification

How to Decide What to Do (long-term)

- Select three demonstration programs/partnerships (F18, B2, JAST)
- Work with demonstration programs to define TT programs
- Generate a plan that has short, medium, and long-term TT's and perform to plan

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(Worksheet #9)

Page 2 of 2

3.7 DRAFT INVESTMENT MODEL OF $100 MILLION

3.7.1 INDIVIDUAL PERSPECTIVE

Group 2 did not document their individual perspectives for the investment model.

3.7.2 GROUP PERSPECTIVE

Group 2 did not document a group perspective for the investment model.

3.8 INVESTMENT OPPORTUNITIES: CLOSING STATEMENTS

3.8.1 INDIVIDUAL PERSPECTIVE

Each member of Group 2 was asked to revisit their opening statements on the investment opportunities to address the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 2-A

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

- Tools for system understanding - $25M/5 years (logic, timing, topology, architecture)
- Standards for real-time avionics software - $50M/5 years
  - Operating systems (real-time POSIX - multiple processors)
  - Databases
  - Displays
  - Other common services
- Architecture with prototypes - $5M for 5 years
- Test/certification costs - $20M for 5 years

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 2-B

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

Workstation-scale systems that are based on a very general type/class/pattern/method library notion. (We need to continue to improve the performance and flexibility of type-like technology.) Quality of design Web.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 2-D

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

No clear solutions are apparent for the problems and costs associated with upgrades/reuse of legacy systems, but solutions must be found. Recommend pilot projects with actual systems going through upgrades to determine what may be the most cost effective solution(s).

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Please print your name on each page so that information can be properly organized.

(Worksheet #12)

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Name: 2-E

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

Develop tools and process and demonstrate applying existing tools, new tools, etc., toward improving the process of reuse or salvage of legacy systems and associated software. This may include extension of existing projects into the avionics domain plus establishing criteria for future system upgrades that permit these future legacy systems into future new systems.

Tools and Process	\$5M/year for 5 years
Demonstrations	\$10M/year for 5 years
Formalized criteria	\$3M/year for 5 years

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Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

3.8.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

4. AVIONICS GROUP 3 DATA

4.1 OVERVIEW

This section contains the information collected from Group 3 during the working sessions. Group 3 focused on avionics problems and challenges and started with attendee registration form responses to the question: "What do you feel is the major challenge in developing software-intensive avionics/missiles systems?" The information in this section is organized by the forms that the working group members completed.

4.2 PROBLEMS/CHALLENGES: OPENING STATEMENTS

4.2.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to write an opening statement on their views of the software problems and challenges in the avionics domain. The following are their opening statements.

Name: 3-A

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

---

1. We will continue to demand much more functionality from our software systems. Unlike Doritos we cannot say "Go ahead, we'll make more!"
2. We cannot specify, a priori, all the functionality of our systems because the missions and roles our systems must perform always evolve.
3. We cannot make concrete our implementations because as our technologies progress (evolution and revolution) we need to be able to take advantage of the new without losing the old.
4. We build our systems based on models of the world, our vehicles, our implementation platforms, and our understanding of the problem we are solving. All of these models are flawed. How do we understand where the models exist in our systems? How do we predict the effect of changes? How do we know when our model assumptions have been violated? How do the users' tasks map to our models?
5. Integration of parts (in all combinations of new, legacy, modified, updated/corrected, replaced) is an error-prone costly manual effort. How can we understand and validate (or even verify) integration and composition?

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 3-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Perspective

After reading the "Compilation of Unattributed Challenge Statements," I am struck by the consistency of opinion. In those statements that were not simply puffery (75%), the following concerns were repeated in more than 80% of the statements:

- Requirements
- Evolution
- Reuse

Two or three statements were highly similar to mine which I restate as:

Opening Statement

The understanding, synthesizing and management of the broad spectrum of requirements that must be met by future avionics software systems and the translation of these into a coherent viable solution.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 3-C

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

We have been understating the software issue. Our entire civilization rests increasingly on an enormously complex and precarious software foundation, from banking to communication to military operations.

In light of this, it is a national imperative that we address the terrible state of software today: development/modification is way too slow, the costs are way too high, and the code usually does not work perfectly.

Fixing these problems requires a complete paradigm shift. We need new technologies and a new business structure. Remember, the ones and zeroes are free - software costs are salaries and there is an enormous constituency for maintaining the status quo. ARPA can overcome this only by "sticking with" its technology developments longer. For example, DSSA and Prototech have launched technologies with tremendous potential, but the potential will not be realized unless ARPA extends the activity until the payoff evidence becomes overwhelming (as it will eventually).

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 3-D

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

How to build systems that maintain their conceptual integrity during their lifetime and evolution.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 3-E

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

---

1. Achieving an optimum definition of system requirements in terms of functionality in hardware and software for new and future weapon system platforms. Without sound requirements definitions up front system architecture is weak leading to a path of poor design, loss of performance, multiple configuration changes and high LCC.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 3-G

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

1. Software should better assist the warfighter in analyzing and presenting the enormous amount of data that is available in current weapon systems. For example, people absorb information more rapidly if it is graphical as opposed to numerical or textual. The data that we perceive is three dimensional as opposed to 2-D. Finally, many sensors seem to conflict. Only by fusing sensor data can the warfighter make the correct assessment.

2. Software needs to be able to "survive" in situations that it does not suspect. This becomes more critical the more complex the weapon system becomes. In autonomous vehicles, the software should be able to adapt the system (vehicle) if the system is altered (such as being shot through the wings). Today's software cannot adequately sustain an unmanned system that is in a hostile environment.

3. Software cannot adequately capture the "rules of thumb" that are known by war fighters and domain experts. Most of these rules cannot be easily modeled mathematically, but are valuable knowledge nonetheless.

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Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

4.2.2 GROUP PERSPECTIVE

After discussion, Group 3 was asked to reach consensus on the problems and challenges by voting. The following are their group results.

Group 3

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes		Problem
(20)	1.	Architectures that can accommodate evolving requirements and technology.
(12)	2.	Matching appropriate (optimal) technology mix to requirements.
(10)	3.	Synthesizing and managing the customers' real requirements.
(6)	4.	Software cannot adapt itself in real-time to meet unexpected system alteration.
(4)	5.	Lack of understanding on the part of decision makers of the importance of software.
(4)	6.	Cannot create all software desired.
(4)	7.	Integration of system components causes unpredicted/unanticipated results.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #2)

Page 1 of 1

4.3 MAJOR CHALLENGES: CAUSE-EFFECT ANALYSIS

4.3.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to describe their views of the cause-effect relationships that exist among the major problems and challenges. The following are their responses.

Name: 3-A

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

---

3 → 5 A. Inability to evolve (synthesize) systems to meet real requirements because existing system architectures are not flexible to change.

4 → 5 B. Inability to match appropriate technology because existing implementation architecture may exclude some technology implementation by reason of interfaces or performance.

4 → 5 C. Difficulty (and cost) to match appropriate technology because architectures do not have sufficient formalisms that let us understand the effects of replacing one technology solution with another.

5 → 3 D. It is hard to find customer's real requirements because we cannot validate solutions except by building them, and we cannot build them quickly because architectures are not flexible enough to accept changes readily. Even when they (architectures) do, they often do not support all the work functional (performance, reliability, etc.) requirements.

4 → 3 E. Implementations of technologies have many orthogonal attributes so it is difficult to tell if the mix of technology in aggregate satisfy all the customers stated (let alone unstated) requirements.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3) Page 1 of 1

Name: 3-B

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

It seems obvious to me that there is a strong cause and effect between requirements and software system design. Furthermore, because requirements and technology continually evolve, the underlying architecture must be designed to evolve as well. Another point touched on earlier was the use of standards to facilitate software reuse and integration. The fact that all standards evolve over half of their useful life places additional emphasis on the need of a software architecture that can change over time.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 3-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Because software architectures are often not designed to accommodate changes, it is overly costly and time-consuming to respond to evolving requirements and technologies.

Poor capture and management of customer's real requirements leads to unnecessary costs and schedule impact.

In view of current software costs and the growing software content in military systems, defense spending cuts will leave the DoD incapable of maintaining its systems in working order.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 3-E

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

1. Avionics architectures are not capable of accommodating evolving requirements and technologies because growth and space requirement for processing, memory, and I/O are specified only in very rudimentary terms (e.g., 50%, 25%, 4x).
2. Avionics architectures are conceived without full knowledge of potential technology solutions and result in reduced performance for more cost.
3. Evolving requirements of DoD include reductions in war fighters, platforms, and weapons which will require new requirements, technologies, and architectures.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3) Page 1 of 1

Name: 3-G

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

1. Failure to design architectures that can accommodate evolving requirements and technologies will lead to system degradation and cost overruns.
2. Failure to synthesize and manage customer's real requirements will lead to systems that do not provide the desired capability.
3. Failure to design architectures that can accommodate evolving requirements and technologies will shorten the lifetime of the system.

I include the following, even though the Group (#3) is only addressing our top 3 priorities, because I deem this vital.

4. Failure to build software that can adapt in real-time to system alterations (e.g., sensor failure) will lead to the loss of the war fighter's life, loss of equipment; and/or failure to accomplish the mission.
5. Failure to build software that can incorporate user "rules of thumb" will lead to inability to handle situations that cannot be modeled.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

4.3.2 GROUP PERSPECTIVE

After discussion, Group 3 was asked to reach consensus on the cause-effect relationships by voting. The following are their group results.

Group 3

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).

Designing architectures that can accommodate evolving (user) requirements and technology.

Votes Problem

High Priority

(6) Integration of DSSA's and reliability analysis

(9) Definition of avionics architecture definition criteria

(6) Development of architecture definition languages

(7) Development of architecture evaluation criteria

(8) Development of facilities to support dynamic architecture reconfiguration

Low Priority

(3) Integration of avionics architecture and multi-level security

(5) Avionics domain definition

(2) Extend current avionics DSSA domains

(4) Develop avionics architecture analysis tools

(1) Develop tools for mapping of architectures onto new processor architectures (e.g., going from 2 processor to 4 processor configuration)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #4) Page 1 of 1

4.4 MAJOR CHALLENGES: FEASIBILITY ANALYSIS

4.4.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to describe their views on the feasibility of addressing the major problems and challenges. The following are their responses.

Name: 3-A

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Item #	Level of Effort	Likelihood of Success	Probable Benefit
1.	Reliability analysis	2	7	2	3
2.	Aviation architecture definition	5	5	4	5
3.	Aviation architecture definition language	6	4	5	6
4.	Aviation architecture-based system evaluation criteria	8	4	5	6
5.	Dynamic architecture reconfiguration	10	7	6	3
6.	ATD Program	11	4	7	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 3-B

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
• Exploitation of off-board intelligence sensor data on-board strike aircraft	6	6	5
• Use of object-oriented technology in avionics software	6	6	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 3-C

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Integration of DSSA and reliability analysis	3	5	5
2.	Avionics architecture definition (extend DSSA domain)	4	4	5
3.	Avionics architecture definition language	4	4	4
4.	Avionics architecture evaluation criteria	3	3	3
5.	Dynamic architecture configuration	4	4	3
6.	DSSA ATD program	4	4	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 3-D

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Software architecture definition for avionics domain	5	6	7
2.	Integrate reliability analysis	4	6	7
3.	Definition language	6	5	6
4.	Evaluation criteria	4	5	7
5.	Dynamic configuration	5	6	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 3-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Avionics software architecture definition	5	5	7
2.	Integration of DSSA and reliability analysis	3	3	5
3.	Avionics software architecture definition language	5	3	4
4.	Avionics software architecture evaluation criteria	5	5	5
5.	Dynamic software architecture reconfiguration	4	5	7

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Please print your name on each page so that information can be properly organized.

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Name: 3-G

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Integration of DSSA and reliability analysis	3	5	5
2.	Avionics architecture definition	1	5	4
3.	Avionics architecture definition language	1	5	5
4.	Avionics architecture evaluation criteria	1	5	4
5.	Dynamic architecture reconfiguration	5	4	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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4.4.2 GROUP PERSPECTIVE

After discussion, Group 3 was asked to reach consensus on the feasibility analysis by voting. The following are their group results.

Group 3

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Integration of DSSA and reliability analysis	4.0	4.2	5.6
2	Aviation architecture definition	3.8	4.8	5.6
3.	Aviation architecture definition language	4.0	4.4	5.0
4.	Aviation architecture evaluation criteria	3.4	5.0	4.6
5.	Dynamic architecture reconfiguration	5.0	5.0	5.4

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Please print your name on each page so that information can be properly organized.

(Worksheet #6)

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4.5 PROBLEMS/CHALLENGES: CLOSING STATEMENTS

4.5.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to revisit their opening statements on the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 3-A

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

It seems that the consensus of our group was that avionics domain descriptions and architecture formations would be helpful. Key challenges to the generation of avionics systems include: retargeting of functions to new processors and processor topographies; optimization to make that retargeting effective; evaluating avionics-specific attributes of architectures and systems (reliability, safety, security, and performance); real-time reconfiguration of system functions to support mission replanning; failures; and the sharing of resources across weapons systems (aircraft, ships, etc.); and workload reduction for the crew, architectures that support change either evolution or reconfiguration - are critical to the ability of our developers to produce affordable systems because today and in the near term we can only validate that we are building the right system by doing just that building a version and executing it against real-world scenarios. Rapid reconfiguration is required to make this happen.

Procedural note: This voting process has had us agree on the VAGUEST statements in our lists. This made it difficult to proceed from one step to the next.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 3-B

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

- Synthesizing and managing requirements - real (current) and evolving
- Open architectures with the capability to evolve to meet changes in requirements and technology
- Open architecture and standards that allow and promote component integration and software reuse
- Selection of technology that best matches the pool of trained and skilled labor available on the open market - promotes cost effectiveness since labor is the most significant cost in software LCC
- Use of off-board intelligence sensor data on-board strike aircraft

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Page 1 of 1

Name: 3-C

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

ARPA has made great strides recently with its DSSA programs. Additional extensions and broadening is now required. Also, a couple of DSSA advanced technology demonstration programs are needed to help overcome organizational obstacles (traditional software writers defend the status quo because they have a vested interest in it - we need to dazzle higher-level people in their organizations to win acceptance).

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 3-G

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

I believe that primary problems that should be addressed are that of real-time software adaptation/reconfiguration, reducing the pilot workload with better sensor fusion, and architectural design techniques that support a better evolution of the software.

1. As systems, both manned and unmanned, become more dependent on software, it is vital that the software be robust to help the system survive (whether it is adaptive software or has algorithms built-in for every component failure) in the event of component/subsystem failure or destruction. The benefits are potentially enormous in the saving of man and machine.

2. As command centers, cockpits, etc., get more complicated, software must better assimilate the sensor data into a format that is quickly understood by war fighters.

3. Finally, it is critical that software be designed with long-term maintainability in mind. Maintainability really means system enhancement and upgrade. Economically, this is critical to sustaining current and future weapon systems.

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4.5.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

4.6 INVESTMENT OPPORTUNITIES: OPENING STATEMENTS

4.6.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to describe their views on the best investment opportunities for ARPA/SISTO with regard to the major problems and challenges. The following are their responses.

Name: 3-A and 3-F

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Answers to "Drill Down" Questions

1. Configuration of avionics software - decision support
2. Describe/design components; analyze results
3. JAST/DSSA
4. Users need help managing [parameters]
5. Push/pull tools - next question to answer; "What if" answer
6. See page 2 of Investment Opportunities: Opening Statement
7. JAST

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 3-A and 3-F

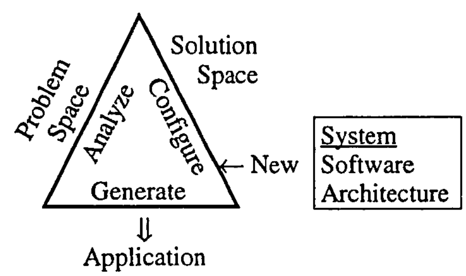
Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. Traceability – Rules/Rationale
   – Derivation
   – Requirements → Test
   "Full Life Cycle"

2. System and Software Architecture – Description and Analysis
   – Visualization
   – Animation



3. Knowledge Representation/Elicitation – Constraints
   – Explanation Generation
   – Scale

4. Software Composition/Integration – Prototype
   – Guidelines/Principles

5. Process – Domain Model

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 3-A and 3-F

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Summary: ARPA needs to support programs that are synergistic from the start and focus on integration of:

Problem space 1. Requirements representation and domain analysis/modeling

Solution space 2. Architecture representation; component design/configuration/distributed decision support

3. Generation/prototyping in a "virtual" environment providing further analysis and feedback

Note: This requires common representation/rationale, configuration management, rule-base, etc. Also, must target distributed/real-time applications.

Finally: It is important to stress scalability in the sense that the technology supports large applications involving large numbers of decision makers with:

1. Uncertainty
2. Conflicting information

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Please print your name on each page so that information can be properly organized.

(Worksheet #8) Page 3 of 3

Name: 3-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Exploration of the synergy between off-board Intel sensor data (both overhead and air breathing, as well as others) and sensors on board strike aircraft (e.g., ESM, radar, SAR, FLIR, . . .). To date, it has been assumed by statement that this exists at best qualitatively. There are several issues involved with this issue. For example, at the lowest level, what (how) is the method to compare positional data from at least two sources with significantly different resolution. Specifically, off-board overheads can be characterized by areas of uncertainty (AOU) on the order of nautical miles. In contrast, on-board sensors and even some off-board air breathing sensors are typically characterized by AOUs on the order of tens to hundreds of meters. Experience with these data show that the use of metrics such as chi-square tend to "over correlate" these two disparate data streams. Other methods based on bi-variate normal distributions tend to discriminate better between two data streams but cause "fragmentation" within a data stream.

The impact is that current data fusion does not handle data streams of disparate resolution. It would be advantageous for ARPA/SISTO to fund research to investigate the co-processing of two or more data streams.

Specifically, consider fusing data from TIBS and TRAP (aka TDDS) broadcasts. That is, single out active radar contacts from a TIBS broadcast and corresponding targets from a TRAP broadcast. Using different combinations of techniques discover what works and what does not in fusing these data streams. A fall out of this line of investigation should be in the area of "Can off boards provide target quality data and how." This would benefit nearly all future weapons delivery systems such as FLL and JAST.

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Page 1 of 2

Name: 3-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Platform set should include minimum of:

1. One or more of AWACS, RJ, and/or JSTARS
2. TRAP ELINT
3. On-board ESM and/or radar

Other data that should be looked at:

1. MTI (true high data rate MTI)
2. IRINT (e.g., DSP and FLIR)

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Please print your name on each page so that information can be properly organized.

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Name: 3-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

1. Honeywell will be delivering a vehicle management system (VMS) development lab to Lockheed for the ASTOVL/x-32, under Honeywell IR&D. It will include militarized Boeing 777 avionics and a software development station. Some early control studies involve reusable control specifications and ARPA-sponsored Domain Specific Software Architectures for dramatic cost reductions (potential factor of 72). To overcome organizational inertia, we need impressive demonstrations. Together with JAST, fund the extension of the VMS lab to include:
   - Integrated DSSA/control analysis tools
   - Hardened specialized GUI-derived from ARPA-sponsored DoME technology (Prototech)
   - Integrated GN&C/display software using DSSA as integrator
   - Complete flight control demonstration in real-time with real hardware spanning control laws and flight director display. Then let the JAST program fly it.
2. Similar reusable GN&C demonstration program for missiles using DSSA.
3. Similar reusable GN&C demonstration.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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Name: 3-E

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

ARPA should select candidate platforms that can be used as a basis to model next generation warfighter environments (e.g., beyond F-22, JAST, and B-2). ARPA should predict future missions, threats, and operation environments using and developing the latest software models and modeling techniques to provide high-resolution user in the loop simulations. ARPA should apply and develop sample application-specific domain software architectures and evaluate each architectures or subarchitectures potential to provide best software technology value to future warfighter avionics environments. The objective is to match evolving software technology with evolving warfighter requirements.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 3-G

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

---

1. Invest in the development of software that can adapt itself in real-time to unexpected system changes. As more systems become unmanned (UAV, UGV) or fly-by-wire (F-22, RAH-66 Comanche, etc.), systems must be able to adapt to changes in the vehicles aerodynamics. For example, Japan is doing research into adaptable, unmanned, sub-scale helicopters incorporating fuzzy logic. The helicopters are flown into telephone poles where the rotors sustain significant damage. The aircraft is then able to stabilize and fly to safety. The benefits of this research are enormous primarily in the ability to save war fighter's lives and recover damaged equipment.

2. The second most important area for potential investment is in more support by software in sensor data fusion and sensor display. "Intelligent" software techniques such as fuzzy logic and neural networks can reduce the workload on aircraft pilots, tank commanders, missile control station operators and others. This would increase the likelihood of system survivability and mission success.

3. The third area would be in the development of architecture design methodologies, techniques, tools, etc., that could produce software that could evolve as requirements/features are added to systems over the weapons life-time.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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4.6.2 GROUP PERSPECTIVE

After discussion, Group 3 was asked to reach consensus on the investment opportunities by voting. The following are their group results.

Group 3

Investment Opportunities: Opening Statement
Group Perspective

Please describe what the group considers to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

(Not Ordered)

- Adaptive software for real-time reconfiguration in response to unmodeled circumstances, e.g., for unmanned vehicles
- Underlying technology; distributed decision support tools integrating the three facets: problem space/understanding, solution space/configuration, application space/generation
- Fusion of on- and off-board dissimilar data streams including TRAP, TIBS
- Development of next-generation-scenarios and engagement simulations to drive architecture assessments
- Strengthen/drive technical transfer efforts with exciting ATD's (e.g., DSSA for X-32, JAST, missiles)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #9)

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4.7 DRAFT INVESTMENT MODEL OF $100 MILLION

4.7.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to describe their views of how a hypothetical $100 million budget should be invested to address the problems and challenges. The following are their responses.

Name: 3-A and 3-F

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive software	$6M	$2M	3
2. Decision support tools (architecture support composition, traceability, etc.)	50	10	5
3. Sensor fusion algorithms	6	2	3
4. Advanced simulators	21	7	3
5. Scale up/integrate*	17	5.66	3
Note items 1, 4, and 5 could be part of 2.			

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10) Page 1 of 1

Name: 3-B

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive software (18.33)	$5M	$1.25M	4
2. Software development support tools (19.5)	25	5	5
3. On/off fusion (17.5)	25	8.33	3
4. Next generation MITL (27.66)	25	6.25	4
5. Strengthen AID (17.0)	20	4	5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 3-C

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive software	$10M	$2M	5
2. Decision support/underlying technology	30	6	5
3. Sensor fusion	10	2	5
4. Engagement simulation systems	5	1	5
5. Drive demonstrations, e.g., DSSA for JAST, X-32, missiles	45	9	5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 3-D

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive	$30	$6	5
2. DSS for software development			
3. Fusion	30	10	3
4. Next generation simulation	30	10	3
5. Strengthen technical transfer	10	5	2

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 3-E

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive software for RT catastrophic damage	$10	$3, 3, 4	3
2. Decision support tools for software development	5	2, 3	2
3. Fusion of on-board/off-board	10	2, 3, 5	3
4. Next generation, MITL warfighter scenario-based simulation	70	10, 20, 20, 20	4
5. Strengthen/drive ongoing technology transfer efforts via ATDs (e.g., DSS on X-32, JAST, and leadership)	5	5	1

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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Name: 3-G

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
From the group perspective (#3) on the Investment Opportunity form			
1. Real-time adaptive software for unmanned or fly-by-wire manned vehicles to adapt to sudden system alterations	$49M	$9.8M	5
2. Decision support tools for software development	7	3.5	2
3. Fusion of on/off-board data in TRAP/TIBS context	24	6	4
4. Next generation, man-in-the-loop warfighter scenario-based simulation	15	1.5	10
5. Drive ongoing technical transfer efforts via ATDs (e.g., DSSA on X-32)	5	2.5	2

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

4.7.2 GROUP PERSPECTIVE

After discussion, Group 3 was asked to reach consensus on the investment model by voting. The following are their group results.

Group 3

Draft Investment Model of $100 Million
Group Perspective

Please indicate how the group would invest $100 million in the challenges of avionics/missiles software and software technology. Also, please indicate whether any given challenge investment should be spread over more than one year. Try and ensure that exactly, $100 million is invested. (For simplicity, please presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Adaptive software development	110/ 18.33	-/ 4.3	25/ 4.25
2. Decision support tools for software development	117/ 19.50	-/ 5.1	19/ 3.8
3. Fusion of on/off board data in TRAP/TIBS context (adv. demonstration)	105/ 17.50	-/ 5.0	21/ 3.5
4. Next generation man-in-the-loop warfighter scenario-based simulation (software aspect per SISTO)	166/ 27.66	-/ 5.8	29/ 4.8
5. Strengthen/drive on-going technical transfer activities	102/ 17.00	-/ 5.7	18/ 3.0
Notes *1 - Value for group total. *2 - Average. *3 - Computed from *2's.	*1/ *2	-/ *3	*1/ *2

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(Worksheet #11)

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4.8 INVESTMENT OPPORTUNITIES: CLOSING STATEMENTS

4.8.1 INDIVIDUAL PERSPECTIVE

Each member of Group 3 was asked to revisit their opening statements on the investment opportunities to address the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 3-A and 3-F

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missile. Please include some notion of levels of investment, and supporting rationale.

I recommend ARPA/SISTO invest in fostering cooperation between the AI and software engineering committees, targeted toward real-time, embedded application domains. Topics would include:

- Knowledge solicitation ↔ requirements engineering
- Genetic algorithms ↔ software architectures
- Machine learning ↔ rationale capture
- Knowledge representation ↔ object-oriented databases
- Frameworks ↔ patterns
- Plans ↔ configuration scenarios
- Automatic programming ↔ software composition and synthesis

(The list goes on but that is all I have time/could think of.) These are domain independent technologies. What would be domain-specific would/could be:

- Sensor fusion algorithms
- Self-configuring and self-aware software components and architectures
- Signal processing in general
- Mission planning

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(Worksheet #12)

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Name: 3-B

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

From what I have heard (and from previous thoughts) ARPA/SISTO should invest in "leadership." That is, they should establish a vision with goals (using industry input) and then seed programs which have potential to meet these goals.

I would advise ARPA/SISTO to look more closely at the commercial world (maybe even have conversations/forums with them) and identify niches that are not filled. By commercial I do not mean the usual list of government contractors; I mean "real" software companies; e.g., Borland, CPS, CADRE, Code Center, Microsoft, Lotus, ... These companies do not have all the answers, but the things they provide save the government billions of dollars.

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(Worksheet #12)

Page 1 of 1

Name: 3-C

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

SISTO needs to select a portfolio of investments spanning basic research, technology development, and interesting demonstrations which will lead to acceptance of new paradigms for software and intelligent systems.

A particular point of interest should be the bridging of the gap between academic research and applications by involving researchers who have familiarity with both areas.

Right now, SISTO faces special opportunities which are very exciting, based on recent programs such as DSSA and Prototech. It is in everyone's interest to continue these activities, with an ATD-phase emphasis.* Also, new technology developments should go forward to feed future ATD programs.

*Do not stop the funding flow at this critical point.

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(Worksheet #12)

Page 1 of 1

Name: 3-D

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

The issues brought up seem to fall into four categories:

1. General domain-independent software engineering such as software architecture definitions and decision support for software development.
2. Very specific research issues such as adaptive software for vehicle control and fusion of on/off-board data.
3. Technology transfer and showcasing including driving ongoing projects closer to practical use.
4. Enabling development such as simulation of next generation systems.

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(Worksheet #12)

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Name: 3-G

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

As I understand our "marching orders" from ARPA/SISTO yesterday, it seems that ARPA is trying to justify its efforts with Congress and not appear that it is simply trying to solve the same problems of 10 years ago (requirements definition, design techniques, etc.). These issues are still with us and should continue to be examined; however, I believe that ARPA should also concentrate on more direct support to the ultimate user: the warfighter. A great deal of what I have heard continues to concentrate on our development "processes" instead of our development "products." The military will continue to rely more on unmanned systems (UAV, UGV) and computer/software-assisted systems (fly-by-wire control systems such as Comanche, F-22, etc.). Therefore, ARPA should recognize the demands on future software systems and concentrate on those issues.

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(Worksheet #12)

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4.8.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

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5. MISSILES GROUP 4 DATA

5.1 OVERVIEW

This section contains the information collected from Group 4 during the working sessions. Group 4 focused on missile problems and challenges and started with a "clean slate" (i.e., they were provided with no prior data.). The information in this section is organized by the forms that the working group members completed.

5.2 PROBLEMS/CHALLENGES: OPENING STATEMENTS

5.2.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to write an opening statement on their views of the software problems and challenges in the missiles domain. The following are their opening statements.

Name: 4-A

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

The major challenge for missile development is automated software development (ASD). This includes software for guidance and control, seeker-sensor and simulation. ASD should be developed to accommodate missile development from concept to disposal and to produce the best product while lowering costs to affordable levels. The development process should include software toolset, to assist the entire missile domain: i.e., G&C (Guidance and Control), sensor-seeker and simulation. A sub-challenge to ASD is a meaningful demonstration project.

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(Worksheet #1)

Page 1 of 1

Name: 4-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Missile systems have evolved from largely analog to digital in short time frame. Even the small, short range "munition type" now have sophisticated digital electronics. Do we have a clear, common understanding of the range of missions of these systems in terms of:

- Physical target (stationary, mobile) (air, ground, space)
- Electromagnetic target (anti radiation, heat-seeking, image)
- Trajectory (short range, medium LOS, medium pursuit, steering waypoint, ballistic)
- Platform (ship, air, ground (mobile and stationary))
- Updates (GPS, radar returns)

What causes differences in essentially some requirements, e.g., coordinate transformation

Missiles essentially do three jobs: find out where they are, find out where they are supposed to be, get there

Given this simplistic understanding, can we come up with common models for missile systems in terms of:

1. External interfaces and connections.
2. Layering of systems from base hardware through high-level applications.
3. Information model or architecture; what is the information structure missiles must deal with (e.g., velocity, acceleration, coordinate frame, latitude/longitude).
4. What are the range of operations from a tow to an ICBM. Why do they differ in seemingly similar missiles.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Name: 4-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

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5. Operational behavior: What are the "standard" ways these operations work. Is this idiosyncratic of the design or common based on similar content.

Finally, why does not the DoD organizational structure lend itself to addressing these questions in terms of a set of suitable architectures, possibly driven by mission complexity? If each new missile is a new start, then how did SLAM manage to integrate a HARPOON airframe, a Rockwell GPS/INS, an MDC guidance and control, [Maverick seeker], [Walleye data link]. Can this provide a pattern for off-the-shelf construction?

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 2 of 2

Name: 4-C

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

- A very [large] good investment in legacy software has been made. It is difficult to recoup this investment in new systems through reuse because:
  1. Mismatch of architecture style
  2. Mismatch of communications style/approach
  3. Optimization to meet performance requirements
  4. Radical changes in underlying operating/run-time system or proprietary operating systems/run-time systems that change radically because they are inflexible.
- It is difficult to separate domain-specific/algorithmic knowledge embedded in code from knowledge about I/O or speed or space "tricks" or optimizations or from "tricks" to make proprietary devices work.

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(Worksheet #1)

Page 1 of 1

Name: 4-D

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

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1. Existing completed software-intensive programs (successes and failures) have not been adequately analyzed to identify critical success factors. Domain segmentation following a broad area analysis would provide insight into both domain-specific problem areas, as well as those areas or factors that would provide leverage across multiple domains. The baseline data is readily available in the form of CSSR data collected by DoD. Analysis is lacking.

   (cost schedule status reports)

2. While software is different from a hardware production effort, as an activity it is not so different from other intellectual activities. Focus needs to be brought to bear on creating processes and development environments that provide a solid systems engineering approach.

3. For a given missile/weapon system too little timely thought is given to issues such as aircraft integration and concept of operations. These concepts need to be crystallized early on as they drive weapon (mission planner and aircraft) throughput, storage requirements, processor speed, weapon seeker time constants (τ) etc. In a general sense, weapons are developed in isolation to a great degree with little thought to "other" requirements (derived).

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(Worksheet #1)

Page 1 of 1

Name: 4-E

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Many challenges remain in software project management where little technology has been brought to bear. Cost and schedule estimating is still a black art. Project monitoring and control rarely follow through on the planned approach. Streamlined software acquisition throws another monkey wrench into the problem for the program office.

Expertise in advanced techniques is lacking - distributed/concurrent systems, object-oriented, domain understanding - lowest bidder cannot staff experts at the engineering costs proposed.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 4-F

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

Problem Example

- BMC4I associated with complex weapon system that is a system of distributed assets

  For example a boost phase intercept system consisting of

  - Shooter aircraft F-15
  - Missile modified HARM (launched from F-15)
  - Kinetic kill vehicle (deployed from HARM)
  - Sensor aboard Air Force platform to detect/track threat missile
  - Battle manager location (air/ground?)

Question

- What are functions to be done (distribution of functions)
  - Where are they done
  - What is done
- To minimize what is communicated between platforms in the shortest possible time and most recent information.

Need

1. A new calculus to determine what is done and where it is done
2. An organization or single SPC to develop weapon system
3. Less

Weapon	Sensor
Shooter	BMC ^{4}I

4. More

Weapon	Sensor
Shooter	BMC ^{4}I

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Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

5.2.2 GROUP PERSPECTIVE

After discussion, Group 4 was asked to reach consensus on the problems and challenges by voting. The following are their group results.

Group 4

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

All 21 issues/challenges are important, and to some extent interrelated. All need to be fixed. At the same time, the top seven (order limited discussion) are:

Votes		Problem
(12)	1.	Organizational/cultural issues involving high cost of software development, automated process, organizational (turf) issues, expense of new technologies expense new streamlined acquisition process (of yet undetermined value) antiquated and [compartmented] development process, and SEI Level 1 program offices (do not have process)
(7)	2.	Design and architecture process lacks consideration of integration reuse, evolvability, testing, and technology insertion.
(6)	3.	System of distributed systems leads to problem of how to distribute function and what is done to minimize problems.
(4)	4.	Expertise to apply new technologies is prohibitively expensive.
(4)	5.	No process for analyzing control success factors leads to acceptance of unrealistic bids and approaches.
(4)	6.	Testing and simulation consumes excessive resources.
(5)	7.	Not timely/not sufficient thought to weapon system integration and concept of operations.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #2)

Page 1 of 1

5.3 MAJOR CHALLENGES: CAUSE-EFFECT ANALYSIS

5.3.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to describe their views of the cause-effect relationships that exist among the major problems and challenges. The following are their responses.

Name: 4-A

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

- Difficulty in achieving the data fusion for G&C systems
- Lack of design automation for increasing complexity of hardware and software design
- Lack of methodology for hardware/software co-design
- Inability of present design process to incorporate software execution, concurrency, and parallelism
- Lack of efficient and appropriate software development tools
- Inability to utilize rapid and virtual prototyping
- Inability to treat (technically) the integration of G&C and sensor-seeker-tracker systems
- Lack of automated software development tools and methodology for missile subsystems and their environment simulations

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 4-B

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Lack of appropriate weapon system integration and con ops [concept of operations] because:

- Not clear, common understanding or vocabulary of weapon system missions
- No suitable partitioning strategy

Requirements capture and architecture selection process lacks consideration of -ilities because:

- Quality based on meeting 2168 quality metrics mode SE process
- Little understanding of technical issues surrounding requirements and architecture models.

Process steps and design rationale not captured:

- Too costly to analyze data and look for patterns
- No suitable mechanism for capturing
- Inadequate expertise
- Software seen as backwater, not integrated as part of product team

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(Worksheet #3)

Page 1 of 1

Name: 4-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Design/architecture process inadequate because:

- Procurement is "one system" at a time
- Software architecture not taught as discipline
- Project management metrics focus on lines of code
- Develop process very compartmentalized with hardware/software separate from software, etc.
- Maintenance/enhancement/growth issues costly to consider or just not considered

Culture issues raise language roadblocks because:

- Mid-level executives most threatened by change
- Changes imposed by top often neglect to collect metrics that account for changes
- Improvement not viewed as continuing process but a "big bang"

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 4-D

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

Problem - not timely/not sufficient thought to weapon system integration and concept of operation.

Root causes:

1. Weapon systems developed independently
2. Disconnect in acquisition process
3. Lack for big picture systems integration upfront
4. Acquisition body composed of isolated program offices. Poor coordination all around.
5. Integration offices of government. Lack of experience/training.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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Name: 4-E

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

- Culture Issues
  - Caused by rapid technical development out-pacing education, training, and experience.
  - Also policy changes in acquisition
- Design process lacking - because of inability to test/validate design decisions, lack of full understanding of requirements and need for evaluation
- System of distributed systems - lack of overall architecture, systems developed independently
- Integration and con ops [concept of operation] - lack of overall architecture, incomplete understanding of total system requirements
- Testing - still a largely manual process, low prestige job assigned to less capable staff
- Critical success factors - data not reported up from program offices
- Expertise prohibitively expensive - you get what you pay for

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3) Page 1 of 1

Name: 4-F

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

I. Software per se is too isolated and cannot stand by itself. It is difficult for a customer to recognize the product and its useful aspects.

II. Software must become and associate itself with specific end products for example

- Boost phase interception weapon system
- Attack operations (kill launcher of threat missile)
- Combined intelligence view of real-time battlefield
- MRI processing for medical field
- etc.

III. Organization should more closely align itself with products, weapon system or whatever

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The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

5.3.2 GROUP PERSPECTIVE

After discussion, Group 4 was asked to reach consensus on the cause-effect relationships by voting. The following are their group results.

Group 4

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).

Two generic areas with a very high causal relationship:

1. Complexity - Increasing at a faster rate than our ability to improve our processes.
2. People - Inadequate training or inability to apply training, low compensation, no career path, rewards not based on team compensation, (many entry-level) jobs are boring, large projects "prescribe" technology. Many jobs are brain-numbing, do not "do" engineering.

Other high causal relationships include:

- Design/Architecture Processes - Most complex and difficult to solve. Incorporates subcauses:
  - Software architecture is not taught
  - Not based on software engineering processes and products (documentation-driven)
  - Little understanding of underlying concepts surrounding requirement models
  - Need design automation for increasingly complex systems (software CAD)
  - Methodology for hardware/software co-design (lack of)
  - Present design process does not incorporate software execution, concurrency and parallelism
  - Rapid and virtual prototyping (need)
  - Automated software development tools and methods (need)
  - Implications of design decisions (need to consider)
  - Lack of meaningful metrics based on efficiency and -ilities.
- High-data fusion (no one takes responsibility for capturing system data requirements)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #4) Page 1 of 2

Group 4

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).

- High causal relationship to Problems/Challenges 1. and 7.
  - Acquisition by isolated program office
  - Lack of overall system architecture
  - Incomplete understanding of overall system requirements
  - Subsystems developed independently
- High casual relationship for cultural issues (length not reflective of complexity of the issue)
  - Mid-level executives threatened by change (program manager)
  - Policy and technical advances outpacing education, training, and experience
  - Data not reported up from program office
  - Not sure what to report
  - How to analyze expertise
- High testing and critical success factors (largely a manual process - low prestige job)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #4)

5.4 MAJOR CHALLENGES: FEASIBILITY ANALYSIS

5.4.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to describe their views on the feasibility of addressing the major problems and challenges. The following are their responses.

Name: 4-A

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Organizational and cultural issues:	3	7	7
2.	Design/architecture process:	5	7	7
3.	System of distributed systems:	3	7	7
4.	Expertise to apply new technologies:	3	7	7
5.	No process for analyzing critical success	1	3	5
6.	Testing and simulation consumes excessive:	5	7	7
7.	Not timely/sufficient thought . . . :	3	5	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 4-B

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Challenge	Level of Effort	Likelihood of Success	Probable Benefit
1.	Organizational and cultural issues	7	1	7
2.	Design/architecture process	5	4	7
3.	System of distributed systems and partitioning strategy	5	3	5
4.	Deploy methodologies	5	4	5
5.	Analyzing data	3	5	5
6.	Testing and simulation	5	5	7
7.	Not timely/sufficient thought to integration	5	3	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 4-C

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
1.	4	2	5
2.	4	5	7
3.	3	7	3
4.	1	5	5
5.	2	7	7
6.	7	4	7
7.	3	4	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 4-D

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Challenge	Level of Effort	Likelihood of Success	Probable Benefit
1.	Organizational and cultural issues: high cost of software development.	4	3	6
2.	Design/architecture process lacks considerations of reuse-integration-evolvability-testing, etc.	5	4	6
3.	System of distributed systems lead to problems in distribution of functionality	5	3	3
4.	Expertise to apply new technologies.	5	3	5
5.	No process for analysis of existing data to identify critical success factors.	4	5	7
6.	Testing and simulation consumes excessive resources.	3	4	5
7.	Insufficient thought given to integration concepts of operations.	3	5	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 4-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Organizational/cultural issues	7	3/5*	7
2.	Design/architecture process	4	6	4
3.	Integration and concept of operations	5	4	5
4.	System of distributed systems	4	6	4
5.	Expertise prohibitively expensive	?(4)	0	5
6.	Analysis of critical success factors	3	3	4
7.	Testing	5	3	5

*High success for individual sheltered programs. Low success across the board for all programs.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

5.4.2 GROUP PERSPECTIVE

After discussion, Group 4 was asked to reach consensus on the feasibility analysis by voting. The following are their group results.

Group 4

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

	Level of Effort	Likelihood of Success	Probable Benefit
1.	5	3*/ 6**	6
2.	5	5	6
3.	4	5	4
4.	3	4	5
5.	3	5	5
6.	5	4	6
7.	4	4	6

*global
**local

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #6)

Page 1 of 1

5.5 PROBLEMS/CHALLENGES: CLOSING STATEMENTS

5.5.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to revisit their opening statements on the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 4-A

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

The major challenge is to provide automated software development and design methodology for domain-specific applications. Basic problems are:

- Lack of software environments for design automation
- Lack of informed personnel for implementation of design automation
- Lack of organizational structure to realize efficient hardware/software co-design

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The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Name: 4-B

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

1. Focus on local issues currently stressed. This misses the need for system-wide requirements/architecture understanding.
2. With scope of today's systems, integrated across platforms and distributed, there is no systematic means for partitioning.
3. Lack of a common system understanding vocabulary and concept of operations for missile systems.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Name: 4-C

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

See preceding pages.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 4-D

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

1. Software is hard. If it was easy anybody could do it.

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Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Page 1 of 1

Name: 4-E

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

Major problem areas are primarily managerial. Technology supporting software management may yield the highest payoff. Problems of not having sufficient technical expertise to solve system/software development problems is not going to be solved by more new technology.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7) Page 1 of 1

5.5.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

5.6 INVESTMENT OPPORTUNITIES: OPENING STATEMENTS

5.6.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to describe their views on the best investment opportunities for ARPA/SISTO with regard to the major problems and challenges. The following are their responses.

Name: 4-A

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What problem/challenge is being targeted?

1. Design automation for missile system development: Software tools for process from concept and math models to disposal.

What is the hard issue?

2. Disjoint and manual means have continued to be used and limit the use of current technologies which drive costs higher.

Where have you experienced this issue?

3. Design of GNC systems, sensor-seeker systems, and their environments simulations and prototyping.

What was the impact?

4. With the present manual means, the cost continues to escalate because of increasing complexities.

What might have reduced/mitigated the impact?

5. Automated software tools which increase design accuracy, quality and testability, while reducing costs.

Where can ARPA/SISTO invest that will help

6. Development of design automation process including software tools - complete with distributed and parallel processing.

What programs might benefit?

7. Tri-services missile development program.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8) Page 1 of 1

Name: 4-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What problem/challenge is being targeted?

1. Systems integration testing over lifetime of missile is extremely costly and haphazard.

What is the hard issue?

2. Knowing what to test from a system perspective (the critical states within modes) and to do regression testing with as software gets upgraded, enhanced.

Where have you experienced this issue?

3.

What was the impact?

4. Manual testing and the analysis of the results is very tedious and error-prone, taking months. You can never be confident that all the errors were found or tested correctly.

What might have reduced/mitigated the impact?

5. A machine-readable/processable definition of states and modes that can be used to stimulate and/or analyze test results.

Where can ARPA/SISTO invest that will help

6. In requirements definition languages and translations that can produce input for other tools that instrument, guide, stimulate, or analyze the integration testing or produce scenarios.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8) Page 1 of 1

Name: 4-D

Investment Opportunities: Opening Statement
Individual Perspective

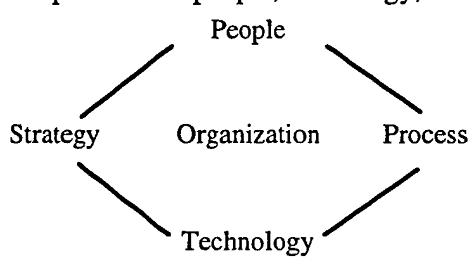
Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What problem/challenge is being targeted?

1. Problem being targeted - There is no organization or process in place for the collection of appropriate program metrics and the subsequent analysis of those factors to clearly identify "critical success factors." These are the factors that once identified can give you tremendous leverage for future programs.

What is the hard issue?

2. What is the hard issue? Tools for data collection and analysis. If you break it down into the following four components: 1. people, 2. strategy, 3. technology, and 4. process.



Assume the organization can be fielded - people hired. What is needed is technology and process for data collection and analysis. A semi-automated tool/methodology to enable rapid collection. Analysis of data on program - programmatic - cost - schedule - technical type data.

Where have you experienced this issue?

3. Where have you experienced this? At Naval Air Aircraft Systems command both in the programmatic areas and in the technical areas.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8) Page 1 of 2

Name: 4-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What was the impact?

4. Impact: Same mistakes repeated over and over again from program to program. (Massive expenditures of dollars.)

What might have reduced/mitigated the impact?

5. An understanding of previous domain programs - critical factors that led to success and/or failure.

Where can ARPA/SISTO invest that will help

6. Creation of tools/methodologies for rapid collection and analysis of data.

What programs might benefit?

7. JSOW, TSAM, JDAM, next generation HARM.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 4-E

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

What problem/challenge is being targeted?

1. Real-time performance cannot be achieved from "clear" high-level language code. Solution always distorts code into unmaintainable form.

What is the hard issue?

2. Real-time requirements not explicit in <u>any</u> design or programming languages. Optimization techniques are weak.

Where have you experienced this issue?

3. (At every turn) guidance, navigation, and control code seeker signal processing.

What was the impact?

4. Distorted, indecipherable, unmaintainable software (i.e., spaghetti).

What might have reduced/mitigated the impact?

5. Real-time performance checks at compile time. Superoptimization. Tool to design hardware configuration needed to meet real-time requirements.

Where can ARPA/SISTO invest that will help

6. Timing annotations for Ada. Advanced optimization: Haskell to real-time code.

What programs might benefit?

7. Future systems. Reengineering of systems currently in pipeline.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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5.6.2 GROUP PERSPECTIVE

No group perspective on the opening statement for investment opportunities was documented by Group 4.

5.7 DRAFT INVESTMENT MODEL OF $100 MILLION

5.7.1 INDIVIDUAL PERSPECTIVE

Each member of Group 4 was asked to describe their views of how a hypothetical $100 million budget should be invested to address the problems and challenges. The following are their responses.

Name: 4-A

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. State-based system integration and testing	$ 5	$2.5	2
2. Real-time annotation and optimization tools	25	7.0	5
3. Missile system integrations methodology tools	20	7.5	4
4. Missile design critical factors analysis tool and methodology	10	2.5	4
5. Missile system integration methodology tool	20	5.0	4
6. Model year technology insertion	20	5.0	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 4-C

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. State-based system integration and testing	$10M	$5M	2
2. Real-time annotation and optimization tools	30	6	5
3. Missile system integrations methodology tools	20	5	4
4. Missile design critical factors analysis tool and methodology	6	3	2
5. Missile system integration methodology tool	14	7	2
6. Model year technology insertion	20	5	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 4-D

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years	
1. State-based system integration and testing	$15M	$ 5M/yr	3	35
2. Real-time annotation and optimization tools	30	10	3	65
3. Missile system integrations methodology tools	10	33	3	95
4. Missile design critical factors analysis tool and methodology	10	3.3	3	15
5. Missile system integration methodology tool	5	2.5	2	25
6. Model year technology insertion	5	2.5	2	100

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 4-E

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Test and integration, state coverage	$40	$ 8	5
2. Design and code performance annotations and optimization	30	10	3
3. Missile-maker design tools	10	33	3
4. Capture and analyze critical design trades	10	3.3	3
5. System integration support	5	2.5	2
6. Model-year technology insertion	5	2.5	2

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

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5.7.2 GROUP PERSPECTIVE

After discussion, Group 4 was asked to reach consensus on the investment model by voting. The following are their group results.

Group 4

Draft Investment Model of $100 Million
Group Perspective

Please indicate how the group would invest $100 million in the challenges of avionics/missiles software and software technology. Also, please indicate whether any given challenge investment should be spread over more than one year. Try and ensure that exactly, $100 million is invested. (For simplicity, please presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. State-based systems integration testing	$16		
2. Real-time annotation and optimization tools	29		
3. Missile design automation tools	20		
4. Missile design critical factors analysis	10		
5. Missile system integration methodology tool	12		
6. Model year technology insertion	12		

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Please print your name on each page so that information can be properly organized.

(Worksheet #11)

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5.8 INVESTMENT OPPORTUNITIES: CLOSING STATEMENT

5.8.1 INDIVIDUAL PERSPECTIVE

Group 4 did not document their individual closing statements for investment opportunities.

5.8.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

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6. MISSILES GROUP 5 DATA

6.1 OVERVIEW

This section contains the information collected from Group 5 during the working sessions. Group 5 focused on missiles problems and challenges and started with attendee registration form responses to the question: "What do you feel is the major challenge in developing software-intensive avionics/missiles systems?" The information in this section is organized by the forms that the working group members completed.

6.2 PROBLEMS/CHALLENGES: OPENING STATEMENTS

6.2.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to write an opening statement on their views of the software problems and challenges in the missiles domain. The following are their opening statements.

Name: 5-A

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

- Requirements definition - analysis - hardware/software architecture definition is non traceable, not well understood, and defined. Requirements changes are not reflected in the hardware/software considerations.
- Methodology in "architecting" a hardware/software solution to a problem.
- Obtaining knowledge on the availability of legacy code (reusable software modules) and the degree of applicability to a problem.
- Given a task, the hardware/software design tradeoffs in many cases may be arbitrary and do not support strong valid engineering decisions.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1) Page 1 of 1

Name: 5-B

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

- Rationalizing and managing complexity
  - Architecture and partitioning strategies (abstraction hiding)
- Adaptability across system life-cycle requirements → post deployment
- Reuse of certified/warranted artifacts
  - What - architecture (domain-specific, system, hardware, software, communications)
  - How - process
- Dynamic "system" reconfiguration
- Model-based development and maintenance
  - Scenario-driven (user)
  - Synthesis across multiple views

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 5-C

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

The emerging threats and advanced algorithms are driving the software requirements for

- Signal/data processing
- Mission planning
- ATR

- Advanced software features required are:
  - Portable
  - Reusable
  - Real-time
  - Low latency
  - Upgradeable

- New environment developments should support:
  - Automation of the development process
  - Software architecture
  - Software decomposition
  - Software partitioning
  - Software integration
  - Reduced cycle time
  - Reduced development costs

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 5-D

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

It is still common practice in missile software design to have a functional design based on global memory access. The justification for this is usually that this is the only way to meet timing requirements. The result of this is highly-coupled systems that are extremely difficult to maintain.

The challenge is to come up with software designs that encapsulate data and functionality, that can accommodate future functional enhancements, that are reusable designs across the domain, and, that most importantly, meet the hard real-time requirements of the missile system.

Additionally, methods are needed which will isolate software from hardware to the greatest degree possible. Single processor systems must be redistributable across multiple processors. Systems should also be able to easily retarget for new processors. These tools should automate these processes to a very high degree.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

Page 1 of 1

Name: 5-E

Problems/Challenges: Opening Statement
Individual Perspective

Please outline what you consider to be the primary software technology challenges in avionics/missiles (as appropriate for your track). In particular, please focus on problem areas (vs. "veiled solutions").

- The accuracy and speed.
- Validation of the software, especially for missile end game simulations.
- Modularized software. So we can efficiently port to different systems.
- From signature point of view; the weapon integration part still need work.
- The hand over between guidance and fuzing.
- A "GUI" to make tread off study easier among RF/IR signature, fly control, aerodynamics, and affordability.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #1)

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6.2.2 GROUP PERSPECTIVE

After discussion, Group 5 was asked to reach consensus on the problems and challenges by voting. The following are their group results.

Group 5

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes — Problem

(5) 1. – Need to communicate
- Wait too long to initiate communication
- Need to "have" whole products and solutions (risk reduction)

– Exchange forums (vehicles)
- Process - ideas - technology

– Motivation to adopt
- Remove cultural/organizational barriers
- Policy
  - Acquisition
  - Best practices

(10) 2. Tools to redistribute/retarget software system
- Parallelization
- Dynamic reconfiguration
- "Late architecture binding"
- "Hardware/software" decoupling
- Process
  - Development
  - Maintenance/upgrade
  - Execution on target environment

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #2)

Page 1 of 2

Group 5

Problems/Challenges: Opening Statement
Group Perspective

Please outline what the group considers to be the primary software technology challenges in avionics/missiles (as appropriate for your track).

Votes — Problem

(5) 3. – Verification of software predictability
- Model-based (parametric)
- Selectable quantitative assessment (establish accuracy thresholds)
- Predict behavior
- Dynamic testing
- Model fidelity

– Establish accuracy thresholds with designated confidence intervals

(13) 4. – Artifact linkage (requirements, specifications, design, and implementation)

Problem:

Adjust impacts of changes to life-cycle products to predict -
- Cost - behavior - consistency - reliability
- Differing model perspectives
- Sematic Consistency
- Canonical Representation (using local expressions)
- Artifact Representation

(7) 5. Portability
- Platform independence
- Dynamic allocation to distributed heterogeneous platforms

(7) 6. Reduce development cycle time
- Rapid prototyping schedule/cost
- Build systems faster
- Compose/generate "partial" solutions

(3) 7. – Adaptability of artifacts across life cycle
– Dynamic system reconfiguration

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Please print your name on each page so that information can be properly organized.

(Worksheet #2)

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6.3 MAJOR CHALLENGES: CAUSE-EFFECT ANALYSIS

6.3.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to describe their views of the cause-effect relationships that exist among the major problems and challenges. The following are their responses.

Name: 5-A

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

- Lack of adequate toolsets results in ineffective traceability in perturbations in the design processes (requirements, design, test, and maintenance) (very high)
- Lack of adequate validation models inhibits rapid development (high)
- Lack of effective T.T. inhibits everything (high)

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Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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Name: 5-B

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

$4 \xrightarrow{H} 2$ Outlier, orthogonal

$4 \xrightarrow{H} 3$

$4 \xrightarrow{M} 6$

$4 \xrightarrow{H} 7$

$4 \xrightarrow{M} 5$

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

Name: 5-C

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

(6) Reduced design cycle $\overset{\text{VH}}{\leftrightarrow}$ tools (2)

(4) Synthesis $\overset{\text{H}}{\leftrightarrow}$ tools (2)

(3) Validation $\overset{\text{M}}{\leftrightarrow}$ tools (2)

(3) Validation $\overset{\text{H}}{\leftrightarrow}$ synthesis (4)

(5) Portability $\overset{\text{M}}{\leftrightarrow}$ adaptability (7)

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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Name: 5-D

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

The inability to facilitate technical transfer inhibits the adoption, or the perceived need, of developing integrated, synthesized project documentation environments.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

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Name: 5-E

Major Challenges: Cause-Effect Analysis
Individual Perspective

Please carefully consider what you have heard, and outline any cause-effect relationships that seem to exist among the major challenges in software avionics/missiles (e.g., inability to meaningfully fuse data leading to difficulty in target recognition). Indicate what you consider to be the relative strength of the causal relationship (low, moderate, high, very high).

- A set of validated software/tools will have the value to redistribute/retarget. It also will give the confidence level that people will use to reduce the design cycle.
- The knowledge of existing software will reduce the development time [for] rapid prototyping.
- Portability will also lead to rapid prototyping.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #3)

Page 1 of 1

6.3.2 GROUP PERSPECTIVE

After discussion, Group 5 was asked to reach consensus on the cause-effect relationships by voting. The following are their group results.

Group 5

Major Challenges: Cause-Effect Analysis
Group Perspective

Please outline any cause-effect relationships that the group considers to exist among the major challenges in software avionics/missiles. Indicate what the group considers to be the relative strength of the causal relationship (low, moderate, high, very high).

Votes | Problem

(16) 1. – Multiple mode operations "plug and play"
- Multiple mission/roles
- Abstraction, model merge/synthesis
  - "Domains getting bigger"
  - "If you think of the problem in this way, then our solutions may work in your domain"

(10) 2. – More intelligence in on-board decision making

(9) 4. – Rapid deployment

(7) 5. – Black box generation/composition of systems
  - Prescribed behavior/performance
  - Predictable cost

(8) 6. – Evaluation performance/behavior of missiles and components

- Treat hardware and software from systems perspective
- Model synthesis
- Late functional allocation to (hardware/software)

Note: There is no "3."

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #4) Page 1 of 1

6.4 MAJOR CHALLENGES: FEASIBILITY ANALYSIS

6.4.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to describe their views on the feasibility of addressing the major problems and challenges. The following are their responses.

Name: 5-A

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

			Level of Effort	Likelihood of Success	Probable Benefit
1.	Technical transfer - need to communicate (20.000)	.10	3	5	4
2.	Tools to redistribute/retarget software system (7.000)	.20	5	5	7
3.	Verification of software predictability (5.000)	.10	4	5	4
4.	Artifact linkage (5.666)	=.26	5	4	7
5.	Portability - platform independence (5.000)	.14	5	5	5
6.	Reduce development cycle time (3.000)	.14	4	4	3
7.	Adaptability of artifacts across life cycle Dynamic system reconfiguration (6.666)	.06	3	5	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #5)

Page 1 of 1

Name: 5-B

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	TT	5	5	5
2.	Dynamic system reconfiguration (process automation, late binding)	4	5	5
3.	Model-based verification, validation, testing	5	5	7
4.	Model representation/expression (semantic consistency)	7	4	7
5.	Portability	3	5	5
6.	Rapid prototyping (architecture-based) – Partial composition/generation – New – Reuse/reengineering	5	5	7
7.	Adaptability across life-cycles	5	5	7

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 5-C

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Communication	1	4	5
2.	Tools	7	5	7
3.	Validation	3	4	4
4.	Synthesis	7	4	7
5.	Portability	4	5	5
6.	Reduced design code	4	4	5
7.	Adaptability	4	4	4

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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Name: 5-D

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Improve technical transfer process	4	1	7
2.	Tools/methods to facilitate redistribution/retargeting of software system	4	4	7
3.	Verification of software predictability	5	3	4
4.	Development of canonical representation that would synthesize data from differing model perspective	4	5	7
4a.	Linkage and generation of software artifacts from requirements through implementation			
5.	Tools/methods to facilitate dynamic allocation and distribution of software across heterogeneous environments	5	3	4
6.	Rapid development cycle using composition/generation methods combined with reuse	4	5	5
7.	Ada protability of artifacts	5	4	4

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 5-E

Major Challenges: Feasibility Analysis
Individual Perspective

Please carefully consider what you have heard, and outline what you consider to be the feasibility of addressing the major challenges. High-leverage is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Need to communicate	3	5	7
2.	Tools to redistribute/retarget	5	3	5
3.	Verification of software predictability	4	5	7
4.	Artifact linkage	5	4	5
5.	Portability	4	4	5
6.	Reduce development cycle time	7	4	7
7.	Portability of artifacts across life cycle. Dynamic system reconfiguration.	4	4	5

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Please print your name on each page so that information can be properly organized.

(Worksheet #5)

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6.4.2 GROUP PERSPECTIVE

After discussion, Group 5 was asked to reach consensus on the feasibility analysis by voting. The following are their group results.

Group 5

Major Challenges: Feasibility Analysis
Group Perspective

Please outline what the group considers to be the feasibility of addressing the various major challenges. Feasibility is a function of the level of effort likely required to address the challenge, likelihood of success, and probable benefit to be derived (scale: very low=1, low=3, medium=4, high=5, very high=7).

		Level of Effort	Likelihood of Success	Probable Benefit
1.	Communication	4	4	6
2.	Redistribution	5	4	6
3.	Verification	5	4	6
4.	Models	6	4	7
5.	Portability	4	4	5
6.	Rapid prototype	5	4	5
7.	Adaptability	4	4	5

Note: These are averages.

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(Worksheet #6)

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6.5 PROBLEMS/CHALLENGES: CLOSING STATEMENTS

6.5.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to revisit their opening statements on the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 5-A

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

- Integrated toolsets are needed to evaluate impacts of perturbations to all phases of the life cycle design processes to each of the phases (i.e., what impact does a change in requirements affect software architecture, and vice versa).
- High-level abstraction models are needed to model hardware and software.
- Artifact linkage required to analyze software design process.

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(Worksheet #7)

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Name: 5-B

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

- Transition and adoption of technology
  - ACD policy
  - Incentives and rewards
  - Experimental design
- Model-based development and maintenance
  - V, V&T
  - Canonical representation and expression
  - Adaptability
  - Semantic consistency
  - Architecture-driven

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7)

Name: 5-C

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

- Artifact linkage is key to design flowdown
  - Requirements
  - Specifications
  - Design/synthesis
  - Implementation
- Tools to redistribute/retarget software development
  - Parallelization
  - Dynamic reconfiguration
- Reduced design cycle
- Portability

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #7) Page 1 of 1

Name: 5-D

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

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1. Development of the methodology required to decide a system through various "views," and to be able to synthesize the data from these views into a central data structure. To then be able to specify one view, which would automatically reflect into portions of the other views. To be able to manage the consistency among these views at all levels of abstraction of the system.

2. Develop tools to isolate software from hardware in order to facilitate redistribution of software to "N" processors, or to retarget for new processor(s).

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(Worksheet #7)

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Name: 5-E

Problems/Challenges: Closing Statement
Individual Perspective

Consider everything you have heard today. Please take as large a perspective as possible and outline what you consider to be the primary software technology challenges in avionics/missiles software and software technology. Try to reduce your list to what you consider to be the top three or four challenges. Include both technical and business considerations.

- Tools to redistribute
- Verification of software predictability
- Artifact linkage

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

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(Worksheet #7)

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6.5.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

6.6 INVESTMENT OPPORTUNITIES: OPENING STATEMENTS

6.6.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to describe their views on the best investment opportunities for ARPA/SISTO with regard to the major problems and challenges. The following are their responses.

Name: 5-A

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

- Integrated tools to facilitate the automatic production of software incorporating the following aspects of the design process:

  - Requirements definition
  - Requirements analysis
  - Concept definition
  - Hardware/software co-design (Advanced development)
  - Hardware/software co-design (Production)
  - PDSS (Post department software support)

  These tools must incorporate the iteration and perturbations on "and of" each aspect above.

1. Problem/challenge being targeted:

   Software for modern missile systems is being developed from unclear and sometimes unknown requirements as new requirements. As new requirements are inserted into the process, these are being done without regard to affects on the resulting design. There is currently no way to trace and analyze impacts of these perturbations on all aspects of the design, development and maintenance phases of the process.

   Automated software design techniques (tools) that are within a DSSA are needed to facilitate, expedite, and verify the correct implementation of the design and to verify

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 5-A

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

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conformity to the specific requirements. This automation must incorporate software reuse (legacy software components), reengineering, software/hardware co-design, software V&V, documentation and maintenance. This tool must allow "hyper-code" and code browsing from co-operating facilities (should be everybody involved with DoD-DOE-DOT and voluntary commercial industries).

2. The real issue is the development of verifiable and reliable software under the reduced funding, shorter schedules, and longer life cycles.
3. These issues have surfaced in the following Army programs - research and development transition programs: MLRs, MLRs-Improved Fire Control System, Joint Unmanned Ariel Vehicle, Fiber Optic Guided Missile (FOG-M), Enhanced FOG-M (EFOG).
4. Impacts: Most programs were delayed, some incurred a $50M overrun the first year before the Army canceled the program.
5. The impacts in #4 could have been mitigated by the toolset discussed at the beginning.
6. ARPA/SISTO should invest in developing an integrated toolset based upon programs like: DSSA, RAASP, Prototech, Arcadia, STARS, Rapid, HPC, and incorporate traditional design tools like Control-H Meta-H (Honeywell), Matrix-X (ISI), Matlab (Mathworks), GNAT, GNO tools, etc.
7. All DoD programs would benefit in some way.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 5-B

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

Affordability (faster, better, cheaper) (see AVI/MIS)

1. Exploit current investment
   - Architecture-based, domain-specific reuse supported by knowledge agents (intelligence)
   - Reengineering of legacy components to that DSA (process enacted)
   - Model-based development and maintenance
     - View integrated framework
     - Adaptability through/after deployment
2. Predict cost performance and behavior (before deployment)
   - Executable (simulation) ADL
   - Parametric description
   - Extensible, attributive grammar (component, control, communication)
   - Allocation to physical architecture
   - "Plug and play" simulation model
3. Automated "system" composition/generation composition of:
   - Partial generation of some components (DSA [description])
   - Reengineer components

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 5-C

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

- Integrated software design tools that support the development of new or upgrading of legacy systems
  - Provides reduced design cycle
  - Enhances portability of software
  - Documents artifacts
- Integrated software/hardware simulation capability
  - Early concept validation
  - Verifies synthesis/functional design
  - Upgrade demonstration
  - Provides legacy from simulation to target design

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Please print your name on each page so that information can be properly organized.

(Worksheet #8)

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Name: 5-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

The challenge being targeted is the ability to design systems (with the aid of a support environment) in such a way so as to isolate the onboard software from the underlying hardware execution environment to the greatest degree possible. The goal of this is to create systems that are easily migratable to new hardware platforms. This encompasses both scalability (multiprocessor) and the ability to retarget the software system for execution on different processors.

The hard issue is identifying the key elements of the software design that make this possible and supplying a domain architecture that supports it. Also, whatever the key elements are, they should be able to be formally expressed and integrated into a tool that will automate this portion of the software design/implementation process. The last, and most critical issue, is that this approach must satisfy the hard real-time requirements of the system, without imposing an inordinately high overhead cost in either processor, memory, or bus utilization.

The payoff of this technology will be in the reengineering of legacy systems and in the development of new systems and their subsequent upgrades. For example, the Army TACMS missile is currently upgrading from a dual Z8002 processor configuration to a dual Intel 80960 configuration. If a proven tool like this existed, it would presumably automate most of the development of the runtime executive, freeing designers to concentrate on enhancing the functional aspects of the missile.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

Name: 5-D

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

The Honeywell Meta H tool is, in fact, such a tool. However, it has not been proven that it can meet the timing requirements of the system, and the overhead cost is unknown. MICOM is currently investigating this tool by developing the Army TACMS onboard software using Meta H to develop the real-time software to run on two i80960 processors.

MICOM believes, based on our current experience with the tool, that there will need to be further enhancements to the Meta H tool to make it a commercially viable approach.

ARPA/SISTO can help by funding further Meta H experiments designed to stress and mature the technology. Honeywell should also demonstrate the ability to rehost to another processor, such as the TI C30/C40 processor line. A missile domain architecture also needs to be matured through collaboration with industry missile manufacturers and government.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

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Name: 5-E

Investment Opportunities: Opening Statement
Individual Perspective

Consider the output of the feasibility analysis session and everything else you have heard. Please describe what you consider to be the top 5 (or so) best investment opportunities for ARPA/SISTO with regard to addressing the challenges presented by avionics/missiles software and software technology. For each investment opportunity identified, please provide rationale as to why ARPA/SISTO should invest in the challenge. Include, when possible, which programs may potentially derive benefit (e.g., B2, F22, JAST, Hellfire, Harpoon).

- Integrated framework that can accommodate modular software interact, communicate, and upgrade with the least impact of the whole program. Then each modular software can be the representation of different discipline, function, or component.
- For each modular software should be a defined validation process to define the accuracy of the software.
- Efficient software language that can be portable and reusable, upgradeable with upgrade processors; and parallel processing.
- Better data processing and accessing/fusion. Such as missiles still having a problem with fuzing decision when flying close to grazing to sea or ground surface.

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #8)

6.6.2 GROUP PERSPECTIVE

No group perspective on the opening statements for investment opportunities was documented by Group 5.

6.7 DRAFT INVESTMENT MODEL OF $100 MILLION

6.7.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to describe their views of how a hypothetical $100 million budget should be invested to address the problems and challenges. The following are their responses.

Name: 5-A

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partitioning	$10	2	5
2. Concurrent/co-design (hardware/software)	10	2	5
3. Validation, verification, and simulation	30	6	5
4. Infrastructure	50	10	5
*: Without demonstrators.			

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 5-B

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partitioning	$5	5/3	3
2. Concurrent design	10	3+	3
3. Validation, verification, and testing	10	3+	3
4. Infrastructure	75	15	5
5. ATD (additional pot of money)	25	12.5 ≥ 2 projects	2

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 5-C

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partitioning	$10	2	5
2. Concurrent design	25	5	5
3. Validation, verification, and test	15	3	
4. Infrastructure	50	10	5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 5-D

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partitioning support of hardware/software	$15	7.5	2
2. Support of concurrent design of (hardware/software)	20	4	5
3. Validation, verification, and simulation	15	5	3
4. Infrastructure	50	10	5

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Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

Name: 5-E

Draft Investment Model of $100 Million
Individual Perspective

If you were the director of ARPA/SISTO, and you were given $100 million to invest in the challenges of avionics/missiles software and software technology, on what challenges would you spend the money? Also, please indicate whether any given challenge investment should be spread over more than one year. Try and distribute all of, and exactly, $100 million. (For simplicity, presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partition	$10	2	5
2. Concurrent design	10	2	5
3. Validation (verification & simulation)	20	4	5
4. Infrastructure	60	12	5
5. Demonstration	100		

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #10)

Page 1 of 1

6.7.2 GROUP PERSPECTIVE

After discussion, Group 5 was asked to reach consensus on the investment model by voting. The following are their group results.

Group 5

Draft Investment Model of $100 Million
Group Perspective

Please indicate how the group would invest $100 million in the challenges of avionics/missiles software and software technology. Also, please indicate whether any given challenge investment should be spread over more than one year. Try and ensure that exactly, $100 million is invested. (For simplicity, please presume no prior or current funding in any challenge area.)

	Total $	$/Year	Total Years
1. Partitioning	$10		5
2. Concurrent design	15		5
3. V, V&T	15		5
4. Infrastructure	60		5

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #11)

6.8 INVESTMENT OPPORTUNITIES: CLOSING STATEMENTS

6.8.1 INDIVIDUAL PERSPECTIVE

Each member of Group 5 was asked to revisit their opening statements on the investment opportunities to address the problems and challenges and, after consideration of the analysis and group discussions, to write a closing statement. The following are their closing statements.

Name: 5-A

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missile. Please include some notion of levels of investment, and supporting rationale.

ARPA/SISTO should invest the majority of research and development money for software in the services using service demonstrations for proof of concepts.

The priority of dollars should involve these primary programs.

1. Automated synthesis/generation of software
2. Executable architecture description/design language
3. Integrated model view synthesis
4. Design Web - Hyper Code software and documentation
5. Domain architecture/modeling supporting total design processes

---

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 5-B

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missile. Please include some notion of levels of investment, and supporting rationale.

- Abstract problem so that it expresses issues and concerns across multiple domains
- Set research, development, and engineering agendas that reflect domain-indepth concerns (as much as is practical) to leverage ARPA/DoD investment
- Do not forget ATD to stimulate and support technology transition and adoption

The information you provide above will be transcribed, word for word, into the final workshop composite report. Feel free to do freehand diagrams and/or to use multiple pages.

Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 5-C

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missiles. Please include some notion of levels of investment, and supporting rationale.

- The fundamental challenge areas are:
  - Functional design partitioning
  - Concurrent design
  - Validation, verification, and test
  - Infrastructure
- Software development tends to isolation from product development.
- ARPA/SISTO should try and integrate its activities into the RASSP, STO and CSTO evolving products.

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Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 5-D

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missile. Please include some notion of levels of investment, and supporting rationale.

There are still a lot of high-level, somewhat vague notions as to what is needed. Large, integrated environments with grandiose concepts are attractive, but are difficult to define. It is also hard to insure that if such a tool was developed, that it would be useful when applied to real world problems.

I think there are some "smaller" steps that can be taken with pieces of the big picture, that will demonstrate relevant technology that will impact current and future problems.

The development of a missile domain architecture and the maturation of the Honeywell Meta H/Control H tools are examples of projects that can yield significant improvements to missile and other realtime software systems.

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Please print your name on each page so that information can be properly organized.

(Worksheet #12)

Page 1 of 1

Name: 5-E

Investment Opportunities: Closing Statement
Individual Perspective

Consider all the discussion and issues you have heard with regard to where, and how much, ARPA/SISTO should invest in avionics/missile challenges. Please detail below any advice you would like to communicate to ARPA/SISTO on how to "best" invest in the challenges of avionics/missile. Please include some notion of levels of investment, and supporting rationale.

We have determined that the infrastructure is the most challenging problem we need to attack first. All the subfactors such as: 1) integrated model view synthesis, will allow us to reduce the design cycle and do tradeoff studies; 2) executable arithmetic design language; 3) automated system composition/generation; 4) domain architecture/modify process will make the software reusable, legacy; 5) design Web will make the design cycle shorter, more efficient.

The other important challenge is the validation and verification at each level and module of software which will be able to correct the design at early stage, and define the accuracy level. Each software come out should have a known benchmark to define the software's accuracy.

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(Worksheet #12)

Page 1 of 1

6.8.2 GROUP PERSPECTIVE

The groups were not asked to complete closing statement group perspective forms.

Appendix A

Closing Group Presentations

(Draft Slides)

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Group 1

(Draft Slides)

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Group 1

Our Nugget: Validation and Evolution of System Requirements

- Characteristics of a desirable solution (hard problems):
  - Unambiguous representation of requirements
  - Capture multiple views of the system (functional, performance, cost, logistical)
  - Flow down and feedback to design decisions (web?)
  - Supports composition and reuse of requirements

Additional solution characteristics (maybe not as hard)

- Vehicle for engaging user (e.g. simulations)
- Supports trade-off analysis ("what ifs?")
- Provide early system indicators (metrics)
- Version control (part of complete system version control)
- Supports automatic test generation
- Open interfaces
- Supports requirements dependency analysis
- Facilitates requirements changes
- Ease of use and visualization

War Story

- A large beer brewer wanted to use SAP to convert their manufacturing system over to a “power builder” environment.
  - Were unable to recover the requirements or design rationale from reading of the code and/or associated documentation. More importantly, could not distinguish requirements from design decisions.
  - We had to throw everything away and start from scratch.
- Missing link: distinction between requirements and design specifications had not been adequate. (need support for multiple views)

Another war story

- Avionics software written in Jovial: discovered they were about to exhaust the processor capacity for the F-16 mission management software. Goals were to shrink code size and decrease response time.
- Based on source code alone, we had no reasonable starting point from which to begin working. We were unable to reconstruct the design rationales: Which code was optimized for speed and which for memory requirements?
- Consequence: we had to experiment to rediscover the code's intent. Extensive testing was required following modifications.
- Solutions: multiple views would have separated concerns; and automated feedback would have ensured that we understood the rationale for particular code segments.

And another

- Experience with a Windows application.
- Did a small model, waterfall approach:
  - Required two years to complete.
  - We overspecified the system (by accident).
  - Weren't satisfied with the first system
- Later, we implemented a second model of the system using a rapid prototyping approach.
  - Were much more satisfied with the revised system.
  - Had more functionality. (Three times as much code in the improved system.)
  - Completed this in 9 months!

The punch line

- Later, we wanted to add support for a third model. Did this one using the original (waterfall approach) method:
  - Once again, required two years.
  - This provided less functionality than the second system.
  - Users were not as satisfied, because they had been excluded from the evolution of the design.
- Use of the evolutionary approach:
  - Allowed users to participate in directing development efforts towards a more desirable solution.
  - Reduced misdirected effort and the overhead of formal compliance with mathematical specifications.

F-18 Software Maintenance

- On the F-18, three years is required from the time a customer comes with a new requirement before the suggestion is available in an aircraft. Why does it take so long?
  - The user's requests are not described in an unambiguous notation. The user is unable to refine his request until considerable (misdirected) effort has been invested in development.
  - Considerable testing is required, mainly to validate that the solution is consistent with user requests.
- Proposed solutions: More quickly resolve ambiguity and errors in requirements specifications; automatic generation of test cases; better separation of views localizes the impact of changes, thereby reducing the need for global testing following "minor" system revisions.

Captain Bartow's experience

- Lessons learned in the development of one aircraft are not integrated into the code for the next project:
- Example: How to turn a corner in auto-pilot mode.
  - This is expensive because the impact of the oversight is discovered late, and retrofitting the correction may have global impact.
  - If the requirements descriptions of previous systems had been kept up to date, and automatic support for composition of requirements from previous systems were available, these problems could have been avoided.

Investment Strategy

- A: (2 years at $15M) Avionics Requirements Representation (all requirements: functional, performance, cost, reliability ...):
  - Study avionics requirement needs and the state of the art.
  - Develop machine parsable representation
  - Requirements visualization
- B: (3 years at $10M) Integration of multiple views (models)
  - Interactions between models
  - Feedback of design decisions

Investment Strategy (page 2)

- C: (first year: $10M, second and third year: $15M)
  Prototype methodology and tools based on A and B
  - Composition and reuse
  - Validation and trade-offs
  - Requirements evolution
  - Support downstream products (design and test)

Group 2

(Draft Slides)

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GROUP 2

The Problem:

"How to bring legacy systems into new reuse/evolvability systems"

Why is This a Problem?

- Avionics MUST evolve:
  - Changing threat/mission
  - Changing concept-of-operation

    e.g. - Real-time Intelligence info in the cockpit

Why is This a Problem (con't)

- Avionics WILL evolve:
  - Processor Upgrades
  - Sensor/Peripheral changes
- Examples:
  - B2 Inflight Replanning
  - V22 Mission Processor Upgrade
  - F18 Radar Processor Upgrade

What is the Impact?

- Expend Lots of $$
  - Redevelopment
  - Testing and Certification
- "Bathtub Curve"
  - Resulting from "injection" of new "deeper" errors
- E.G., 1:1 bug replacement

Examples of What To Do...

- System Understanding Tools
  - Logic
  - Performance
  - Timing
  - Layout/Data Structure
- Standardization
  - Operating Systems
  - Displays
  - Databases
  - Other Common Services

Examples of What To Do (con't)

- Prototype Architecture Workstations
- Explore ways of attacking the cost-of-testing/certification

How to Decide What to do (Long-Term)

- Select 3 Demo programs/partners (F18, B2, JAST)
- Work with the demo programs to define TT programs
- Generate a plan that has short, medium & long term TT's <u>AND</u> perform to plan!

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Group 3

(Draft Slides)

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AVIONICS

GROUP #3

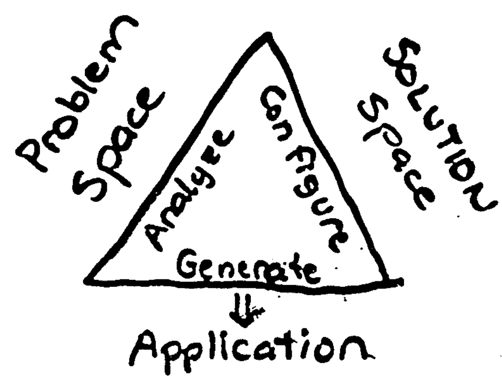
FINAL BRIEFING

1 June 95

GOLDEN NUGGETS

1. REAL-Time adaptive software to correct for potentially catastrophic unmodeled circumstances for unmanned or manned computer assisted (fly-by-wire) systems.
   - UAV, UGV
   - F-22, RAH-66 Comanche

2. Distributed decision support tools for SW development



3. Data fusion of both on-board and off-board sensor/intel data in a context (targeting). Potential ATD.
   - Weapon delivery systems (F-22, Hellfire, AH-64, etc)

4. Next-generation, man-in-the-loop warfighter scenarios-based simulation
   - Beyond F-22, RAH-66

5. Drive on technology transfer of DSSA
   - X-32, etc

INVESTMENT

- No priority given
  ≈ $5M/yr for 4 years

Group 4

(Draft Slides)

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Group 4

ARPA MISSILES

Design/Architecture Process

Not taught

Not automated

Not easily validated

H/W & S/W design compartmentalized

Weapon system designed with little regard for integration & concept of ops.

Causes

Systems
- complexity
- rate of change

People
- inadequate training
- compensation / rewards
- career path
- job satisfaction

Problems

* 1. Organizational / Cultural issues

* 2. Design / Architectural Process

3. Complexity of distributed systems ↑

4. New technology expensive :
   HW/SW, training

5. No process for complete capture & analysis of critical success factors

6. Testing & simulation - expensive

7. Insufficient thought going to integration & concept of operations

Integration & Testing

Not automated

Unplanned and open ended

Organizational / Cultural Issues

High cost of automated SW development

CAD TOOLS FOR MISSILE SOFTWARE

1.) State-based System Integration Testing
2.) Real time amotation & optimization tools
3.) Missile design automation tools
4.) Missile design critical factors analysis
5) Missile system integration methodology)
6.) Model year technology insertion

Opportunity:

State-based Integration Testing

- Reqts described in rigorous form that can be translated to be tool input for simulation/scenario development/test analysis

Impact/Benefit:

Greater confidence in Validation/verification in days rather than months

Anecdote:

Latent errors discovered after deployment despite significant human effort in testing/analysis

Real Time Annotation & Optimization Tools

1. Real time rqts not explicit in Design or code

2. Translate "clean" high level code to super optimized object code

Benefits

1. maintainability (50%)

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Group 5

(Draft Slides)

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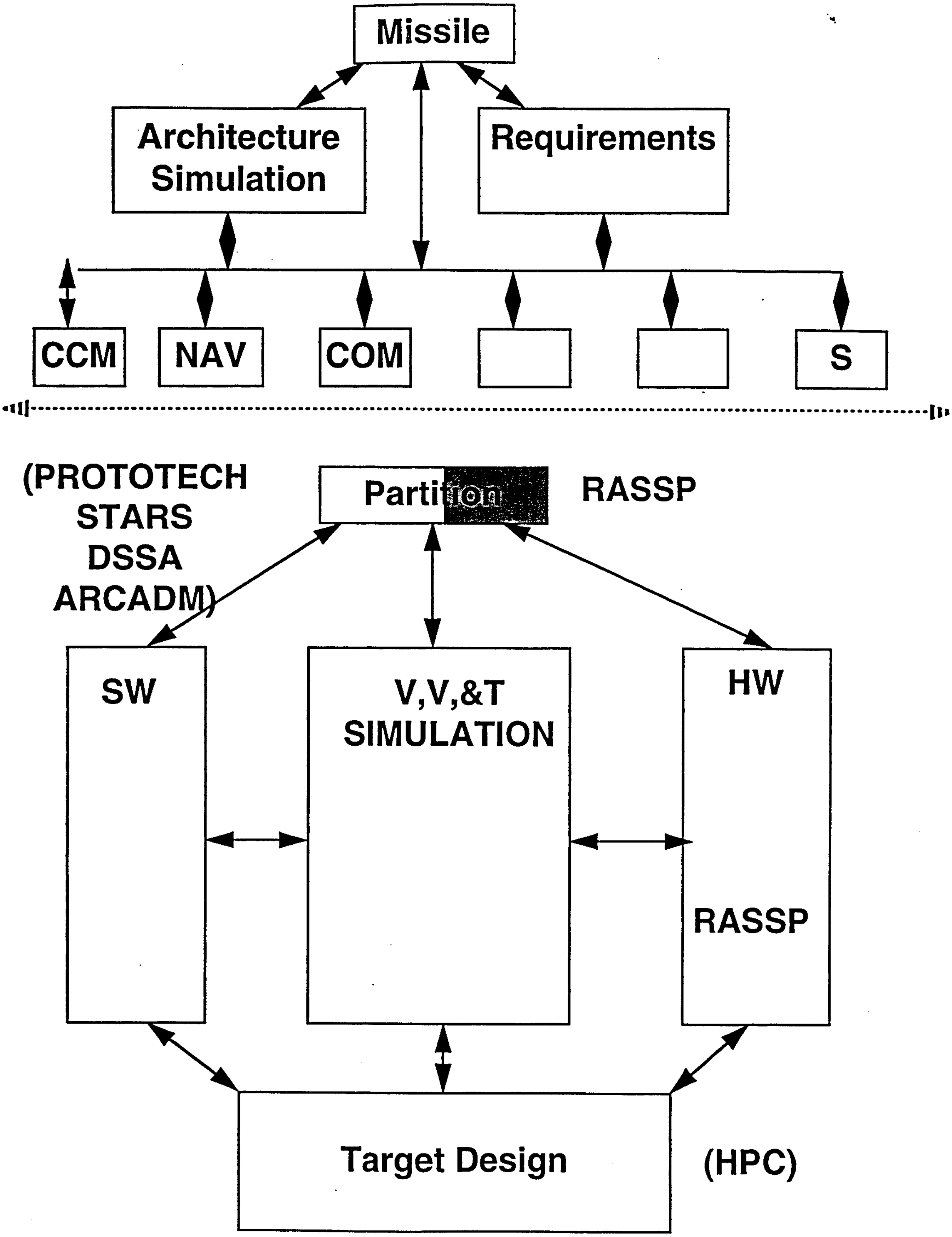
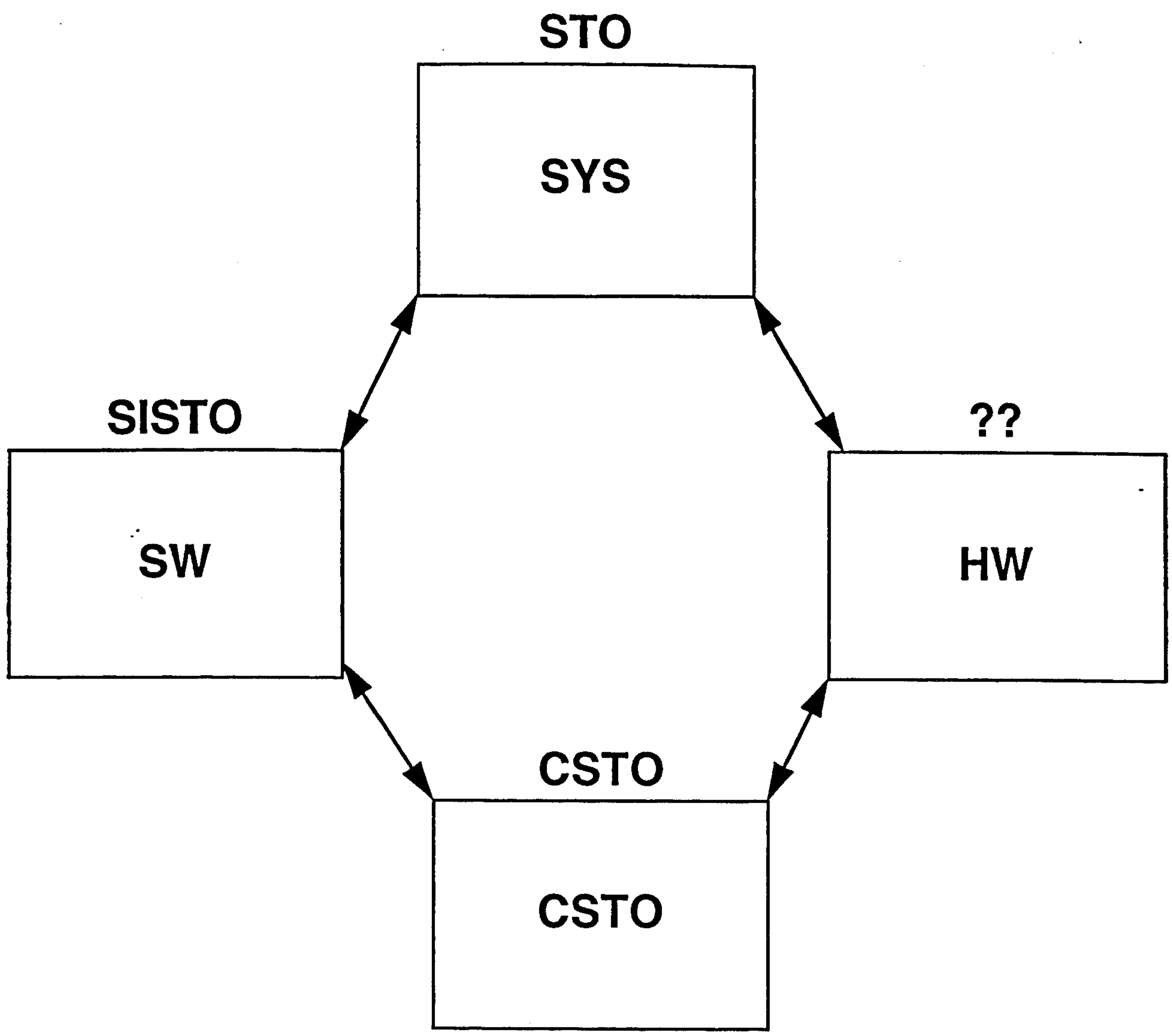
Group 5

System Drivers
(Year 2000)

- Multiple Mode Operations
- Multiple Mission/Roles
- Greater On-board Intelligence & Decision Support Capability
- Reduced Design Cycle
- Early Evaluation of Performance/ Behavior


Missile
Architecture Simulation
Requirements
CCM
NAV
COM
S
(PROTOTECH STARS DSSA ARCADM)
Partition
RASSP
SW
V,V,&T SIMULATION
HW
RASSP
Target Design
(HPC)


STO
SYS
SISTO
SW
??
HW
CSTO
CSTO

Major Challenges

• Challenge	$
• Partitioning	10
• Concurrent Design	15
• Validation, Verification, & Test	15
• Infrastructure	60

- **Infrastructure**

  (Integrated Decision Support - design architecture Trades)

  - (13) Integrated Model View Synthesis
  - (10) Executable Architecture Description Language
  - (17)Automated System Composition/ Generation
  - (7)Domain Architecture modeling the supports process
    - » Commonality
    - » Variability
    - » Optimize
  - (17)Design Web
    - » Traceability Matrix
    - » Design Knowledge Capture

- **Partitioning**
  - 1. Domain Architecture
    - » Commonality - HM
    - » Variability - SW
  - 2. Architecture Trades
- **Concurrent Design**
  - 1. Model System Architecture
    - » Parameterizable Interfaces
    - » Linked Multiple Views (HW,SW,Operator,etc.)
    - » Timing & Control
  - 2. Integrated Product Teams
- **V,V & T**
  - 1. Model Based Benchmarks
  - 2. Legacy from Functional Design to Target Design
    - » Common SW for Simulation, Testbed, Application
  - 3. Plug & Play Harness
    - » Reengineer Legacy Hardware
    - » New Designs

Appendix B

Challenges in Avionics and Missiles Software and Software Technology ARPA/SISTO Workshop Briefing

(R. Bechtold, the Consortium)

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SOFTWARE
PRODUCTIVITY
CONSORTIUM

Challenges in Avionics and Missiles Software and Software Technology

ARPA/SISTO Workshop

May 31 and June 1, 1995

Richard Bechtold

This material is based in part upon work sponsored by the Advanced Research Projects Agency under Grant #MDA972-92-J-1018.
The content does not necessarily reflect the position or the policy of the U.S. Government, and no official endorsement should be inferred.

SOFTWARE PRODUCTIVITY CONSORTIUM

Agenda

Day 1

- Introduction
- Perspectives
- ARPA and JAST Tracks
- Problems/Challenges Analysis Working Session
- Presentation of Results/Conclusions

Day 2

- Investment Rationale Working Session
- Presentation of Results/Conclusions
- Workshop Conclusions and Next Steps

SOFTWARE PRODUCTIVITY CONSORTIUM

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SOFTWARE PRODUCTIVITY CONSORTIUM

Introduction

- Administrative Information
- Introductions
- Workshop Objectives
- Workshop Approach

Administrative Details

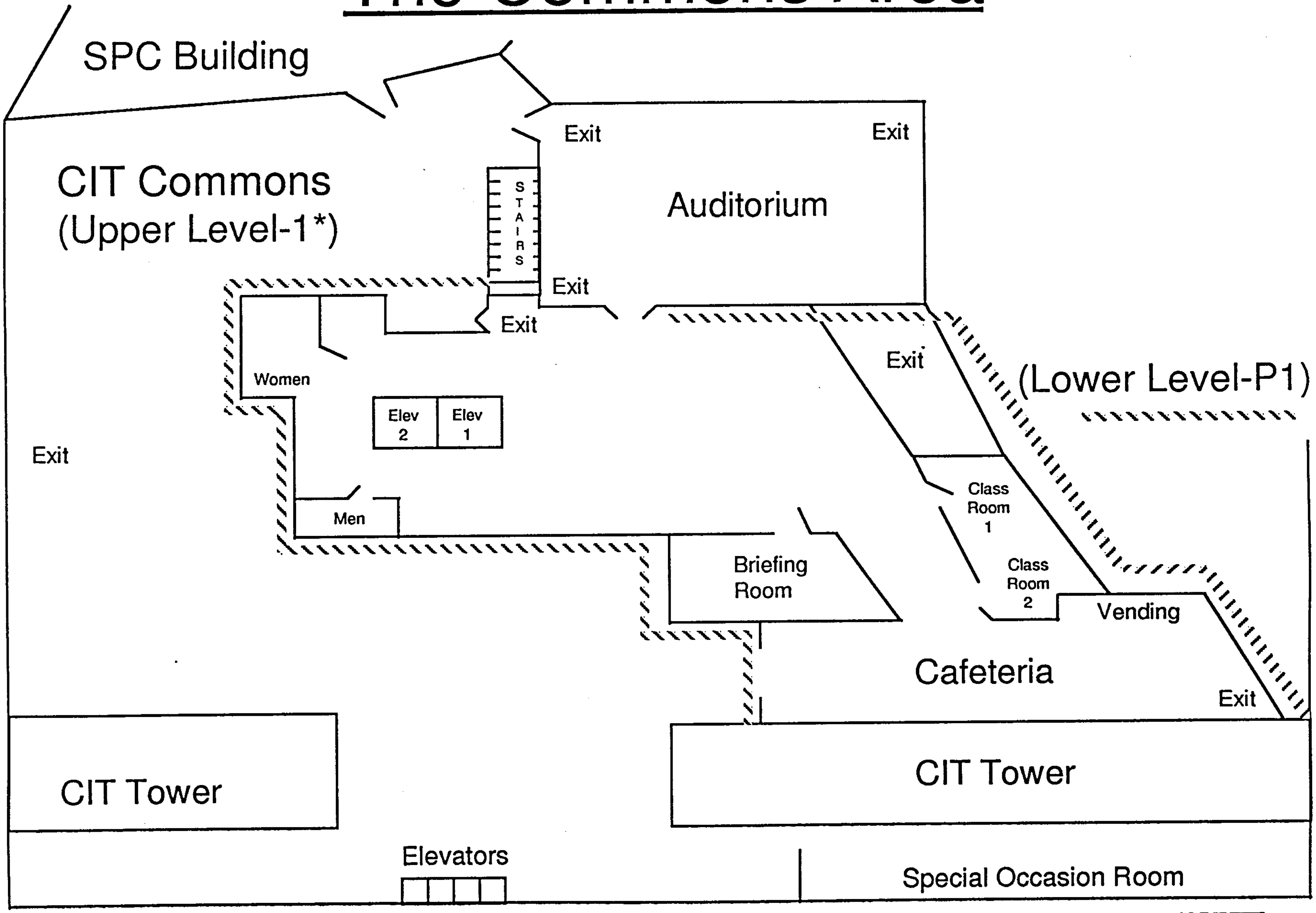
- Badges and escorts
- Facilities
  - Plenary and combined sessions (Training Room)
  - Working sessions (as assigned)
  - Rest rooms
  - Breaks, lunch, and dinner
  - Emergency exits
  - Smoking (in cafeteria or outside only)

Administrative Details (cont.)

- Incoming messages
  - Message board (first floor)
  - Phone: (703) 742-8877
- Outgoing messages
  - Phones (Consortium reception lobby)
  - Pay phones (cafeteria)
- Parking ("closed" after 6:00 p.m.)
- Dinner

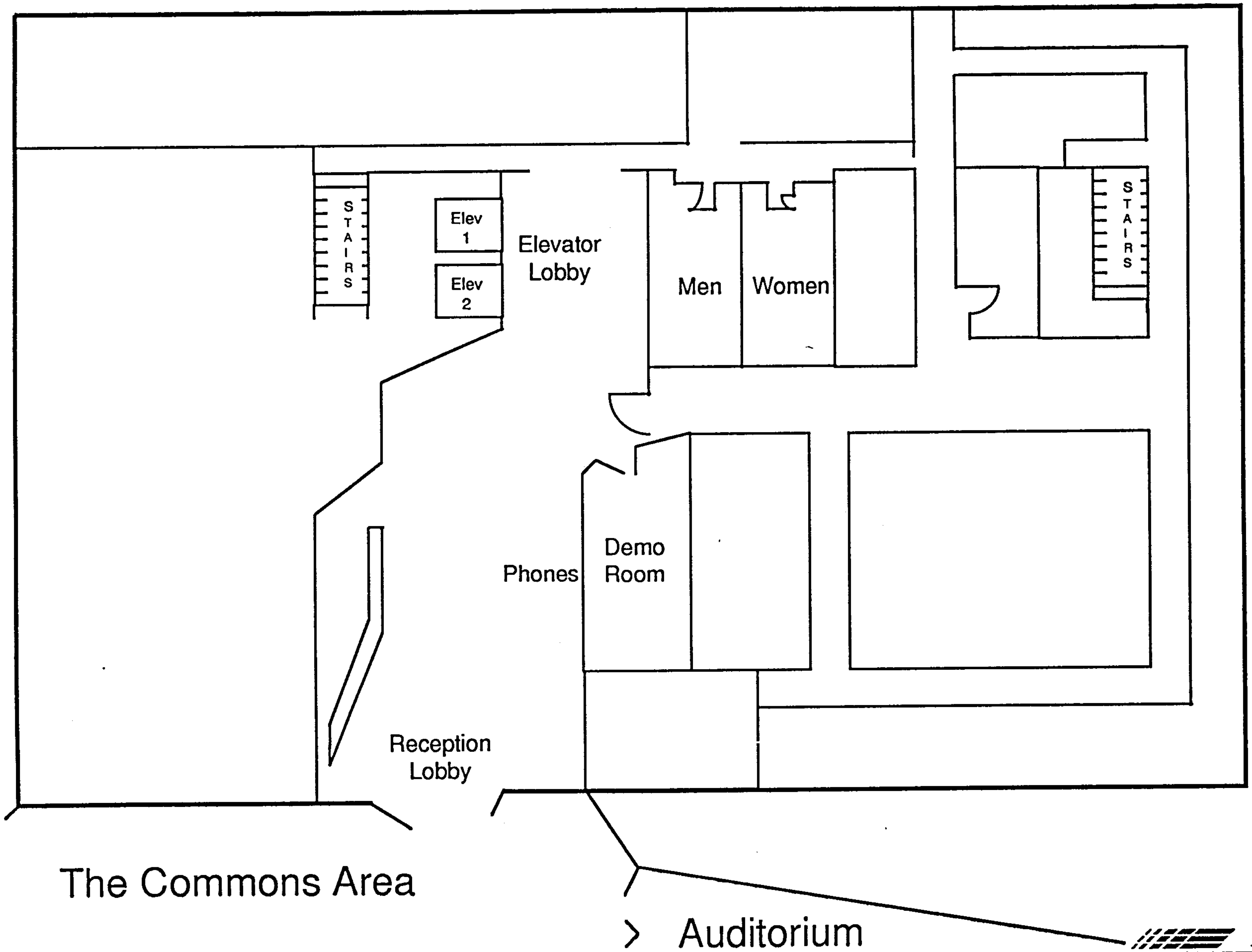
SOFTWARE PRODUCTIVITY CONSORTIUM

The Commons Area



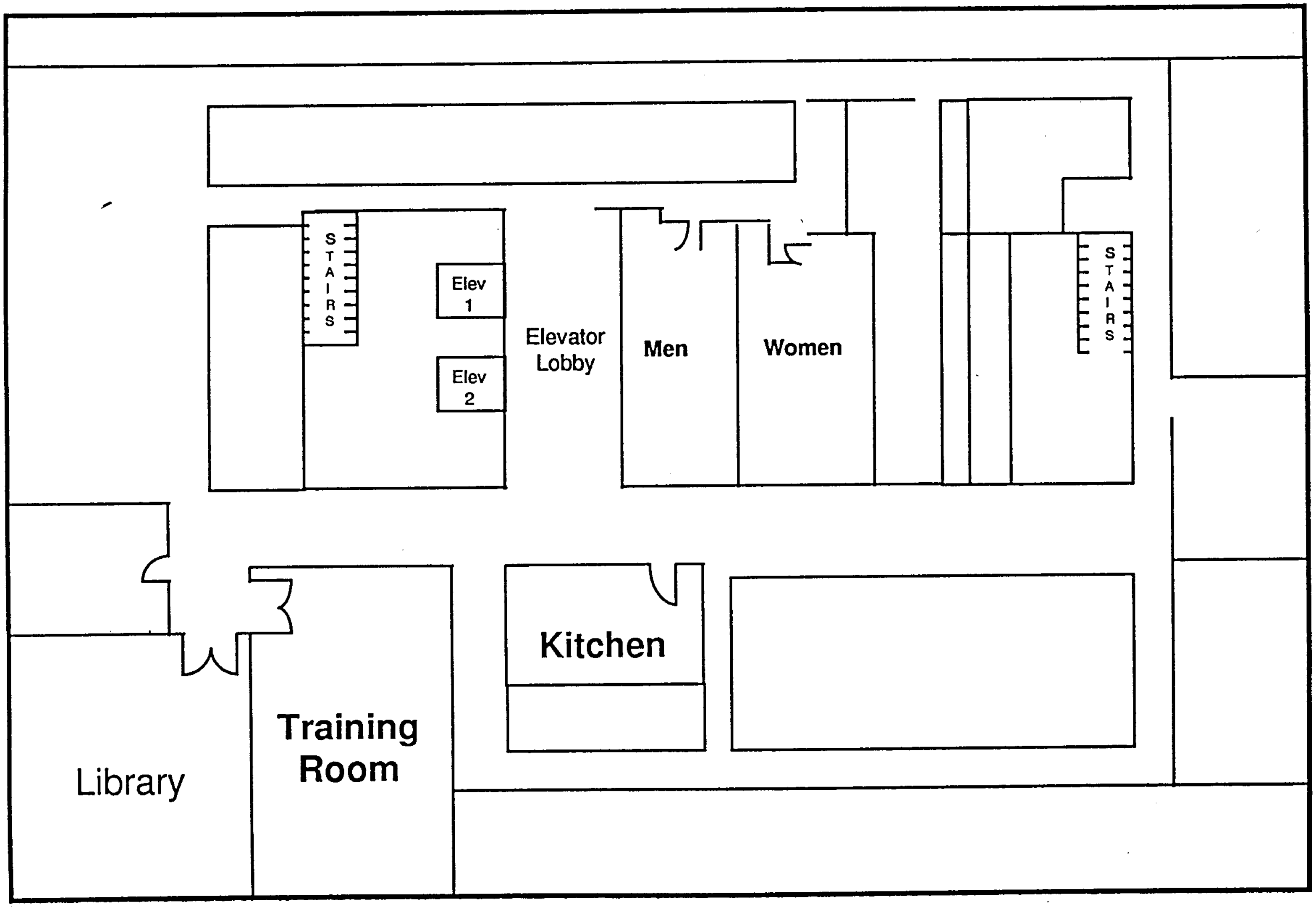
SOFTWARE PRODUCTIVITY CONSORTIUM

Consortium - First Floor



SOFTWARE PRODUCTIVITY CONSORTIUM

Consortium - Second Floor



SOFTWARE PRODUCTIVITY CONSORTIUM

Introductions

- Software Productivity Consortium
- ARPA/SISTO
- JAST
- Workshop attendees

Workshop Objectives

- Identify and describe specific challenges (problems and opportunities) in software and software technology in the avionics and missiles domains
- Analyze the challenges and determine their potential impact on major or important DoD programs
- Prioritize the challenges based on feasibility, impact, etc.
- Develop supporting rationale for highest priority challenges, and potential impact on DoD programs

Workshop Approach

- Establish background and context
- Provide working session orientation
- Divide into small working groups
- Work as small groups to reach workshop objectives
- Periodically regroup into a combined session and share information and ideas

Agenda

Day 1

- Introduction
- Perspectives
- ARPA and JAST Tracks
- Problems/Challenges Analysis Working Session
- Presentation of Results/Conclusions

Day 2

- Investment Rationale Working Session
- Presentation of Results/Conclusions
- Workshop Conclusions and Next Steps

SOFTWARE PRODUCTIVITY CONSORTIUM

Perspectives

- Mr. Mark Gersh, ARPA/SISTO
- Dr. Howie Shrobe, "Evolutionary Design of Complex Software"
- Capt. Jules Bartow, JAST
- Dr. Ed Thompson, "Why This Workshop & What We Need"

SOFTWARE PRODUCTIVITY CONSORTIUM

Agenda

Day 1

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- Workshop Conclusions and Next Steps

SOFTWARE PRODUCTIVITY CONSORTIUM

ARPA (Delphi) and JAST (QFD) Tracks

- ARPA (Delphi) track
  - Avionics and missiles domains
  - Seeded and non-seeded groups
  - Self-facilitated, SPC personnel to assist with workshop process
- JAST (QFD) track
  - Strike aircraft avionics only
  - Extension of strategy-to-task-to-technology applied to JAST avionics software (seeded groups)
  - Facilitated

Common Focus

- Overlap of avionics and missiles sub-domains
- Software and software technology
- Challenges
  - Problems
  - Opportunities

Agenda

Day 1

- Introduction
- Perspectives
- ARPA and JAST Tracks
- Problems/Challenges Analysis Working Session
- Presentation of Results/Conclusions

Day 2

- Investment Rationale Working Session
- Presentation of Results/Conclusions
- Workshop Conclusions and Next Steps

SOFTWARE PRODUCTIVITY CONSORTIUM

Problems/Challenges Analysis Working Session

- Orientation
- Major Challenges Session
- Cause-Effect Session
- Feasibility Session

Problem/Challenges Analysis

- What is a problem/challenge?
- Avoid "veiled solutions"

  Example: "Need faster hardware."

- Challenge area example:

  "Adding functionality to existing systems takes too long and is too expensive due to inadequate architecture considerations."

SOFTWARE PRODUCTIVITY CONSORTIUM

ARPA (Delphi) Process

- Draft opening statements (individual perspective)
- Round-robin presentation
- Open discussion
- Prioritize/vote to reach group “consensus”
- Iterate on the above steps or refine, as needed
- Closing statements (individual perspective)
- Develop summary statements and slides (group perspective)

SOFTWARE PRODUCTIVITY CONSORTIUM

Problem/Challenges Analysis Working Session

- Objective:

  Identify, analyze, and prioritize software technology problems/challenges in your working group's domain

- Forms:
  - Major Challenges: Opening Statement (individual and group)
  - Major Challenges: Cause-Effect Analysis (individual and group)
  - Major Challenges: Feasibility Analysis (individual and group)
  - Major Challenges: Closing Statement (individual)

Problem/Challenges Analysis Working Session (cont.)

- Products:
  - Completed worksheets (individual)
  - Completed worksheets (group)
  - Summary slides
    - Major problems/challenges summary
    - Overview of challenges cause and effect
    - Major challenge feasibility summary
- Return:

  At 5:45 to Training room

Agenda

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SOFTWARE PRODUCTIVITY CONSORTIUM

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SOFTWARE PRODUCTIVITY CONSORTIUM

Investment Rationale Working Session

- Orientation
- Investment Opportunities Session
- Investment Model Session

Investment Rationale Analysis

- What justifies addressing this problem?
- Why should investment into corrective actions be funded?
- What programs or users will benefit?
- What savings could be realized?
- What steps could be taken to address the problem?

SOFTWARE PRODUCTIVITY CONSORTIUM

Investment Rationale Working Session

- Objective:

  Determine the ARPA/SISTO investment opportunities and document supporting rationale

- Forms:
  - Investment Opportunities: Opening Statement (individual and group)
  - Investment Model of $100 Million (individual and group)
  - Investment Opportunities: Closing Statement (individual)

SOFTWARE PRODUCTIVITY CONSORTIUM

Investment Rationale Working Session (cont.)

- Products:
  - Completed worksheets, individual
  - Completed worksheets, group
  - Summary slides
    - Challenge investment rationale summary
    - $100 million investment model overview
- Return:

  At 1:00 to Training room

Agenda

Day 1

- Introduction
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Day 2

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SOFTWARE PRODUCTIVITY CONSORTIUM

Agenda

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SOFTWARE PRODUCTIVITY CONSORTIUM

Workshop Conclusions and Next Steps

- Organize and analyze workshop data
- Develop ARPA/SISTO and JAST reports
- Conduct additional workshops for other domains
- Improve workshop process
  - Workshop evaluation form
- Increase potential of high-impact investment into software and software technology challenges

SOFTWARE PRODUCTIVITY CONSORTIUM

Appendix C

ARPA/SISTO Briefing

(M. Gersh, ARPA)

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Software & Intelligent Systems Technology Office

Briefing to:

ARPA SISTO/JAST
Challenges in Avionics and Missiles Software and Software Technology Workshop
May 31st & June 1st, 1995

Mark Gersh
ARPA/SISTO
3701 North Fairfax Dr
Arlington, VA 22203
(703) 696-2260
mgersh@arpa.mil

New World

Different Threat Environment
Non-Traditional Missions
Joint Operations

Systems (technological & organizational) are long-lived
Decreased Acquisition Budgets
Smaller-Integrated Industrial Base
Commercial-off-the-Shelf

New Challenges for Fundamental Change

SISTO's 10-year Vision

- **Augment human capabilities via *taskable autonomy* and *cognitive support* for individuals & groups to enable affordable, timely, and decisive military warfighting & engineering capabilities**

  "Better Decisions with Fewer People in Less Time"

- **Elements of taskable autonomy and cognitive support**
  - **Information access**
  - **Information reduction and abstraction**
  - **Information comprehension and retention**
  - **Information interpretation and analysis**
  - **Plan formation and decision making**
  - **Intelligent action**

DOD Communities Supported by SISTO

"Traditional and Established Customers"

Operations Community
"Anytime & Anywhere Rapid Utilization of Crises Management Information"

Engineering & Acquisition Community
"Affordable System, Development, Deployment, & Evolution"

"Increased Emphasis"

Intelligence Community
"Comprehensive Situation Awareness & Analysis"

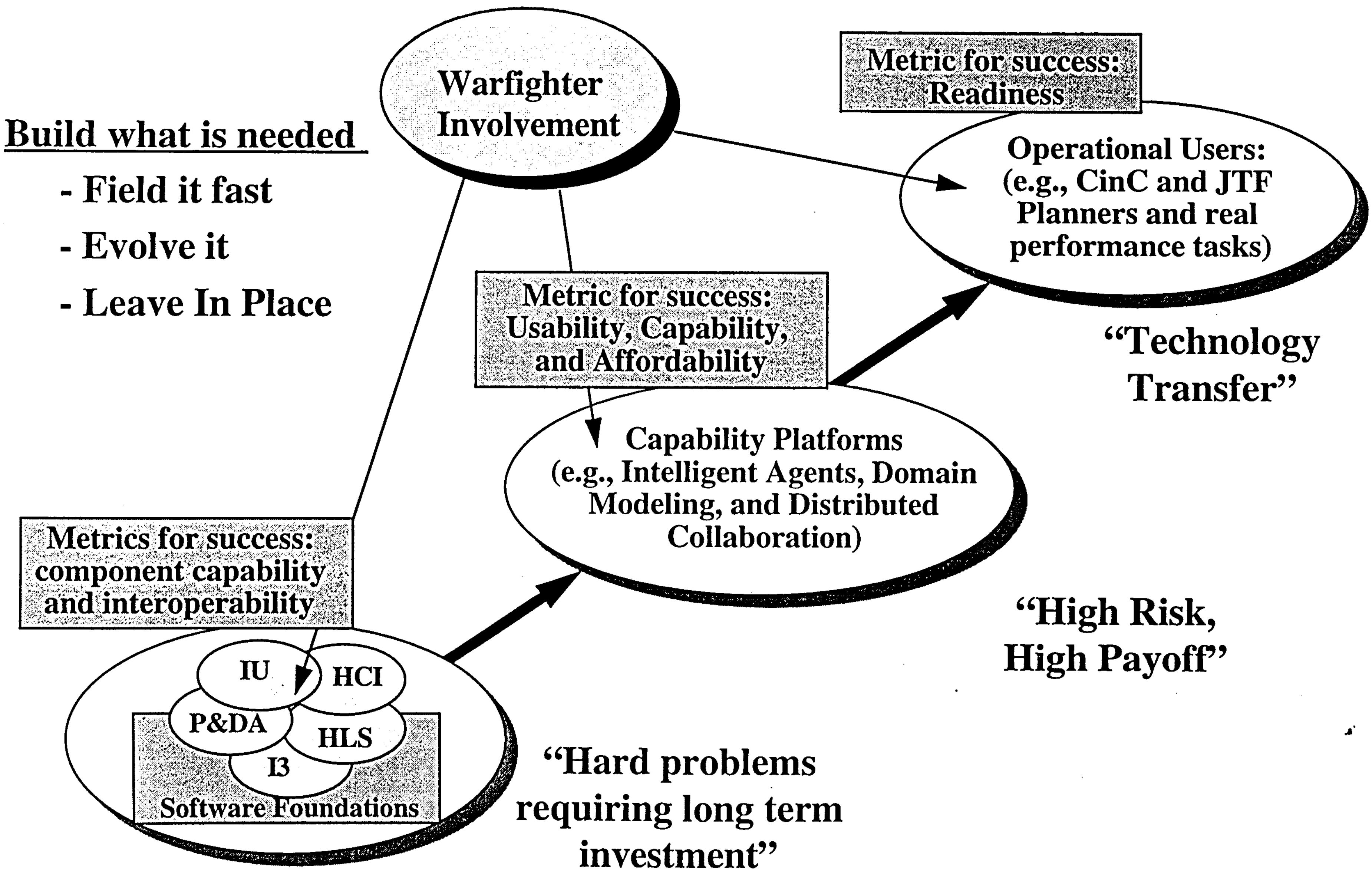
"Cultivating Opportunities"

Personnel Community
"Protection & Enhancement of the Individual"

Example Technology Transition Strategy

<u>Build what is needed</u>

- Field it fast
- Evolve it
- Leave In Place



CURRENT SOFTWARE & INTELLIGENT SYSTEMS PROGRAMS

Application focus across technology thrusts:

Crisis Management

Intelligence

Autonomous Vehicles

Engineering & Acquistion

Design & Manufacturing

Education & Training

Health Care

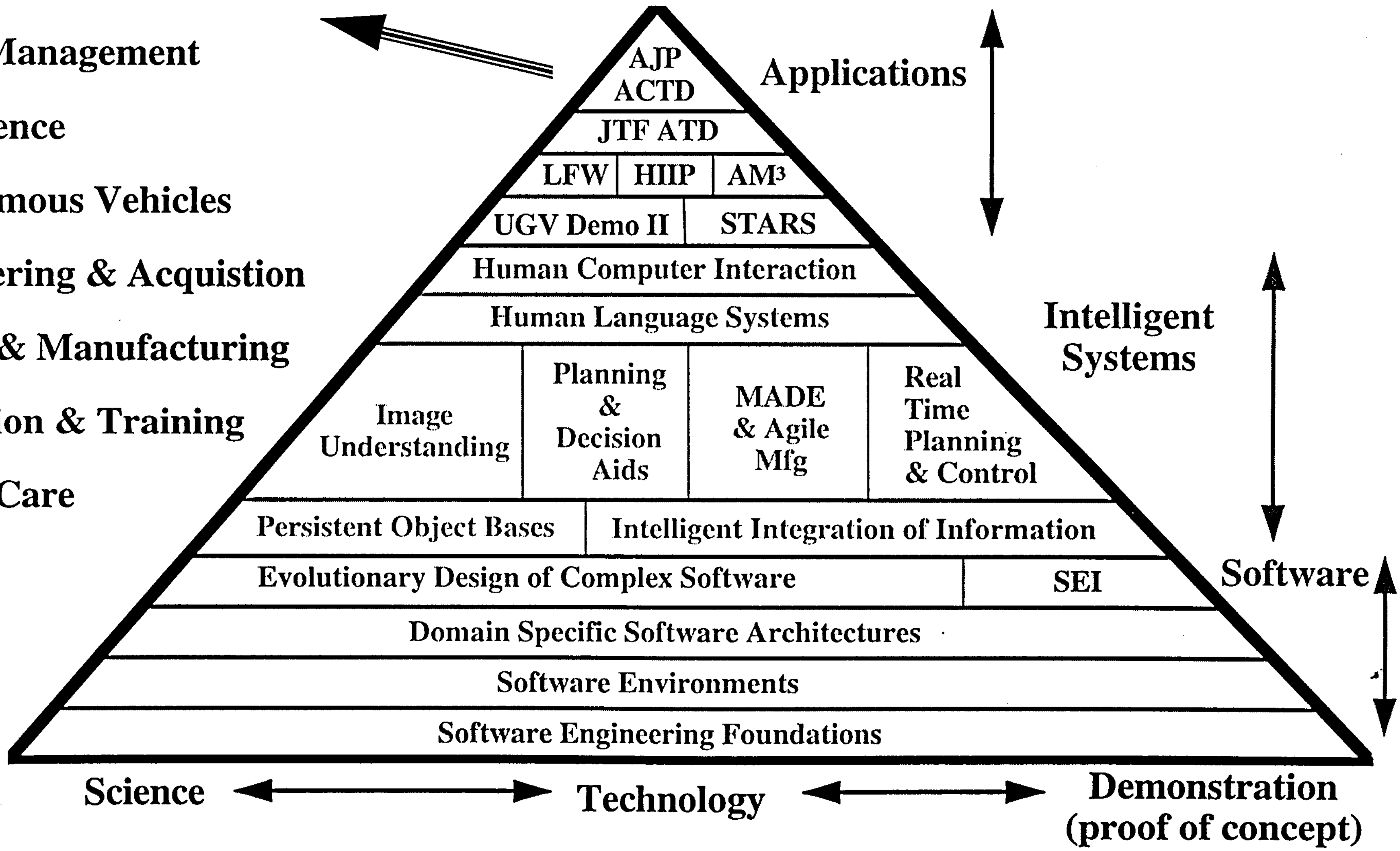
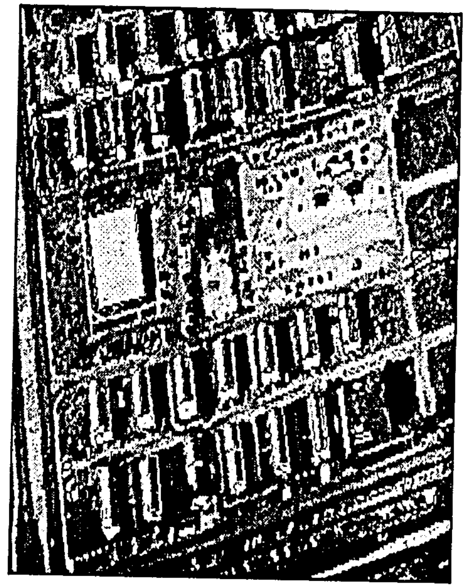
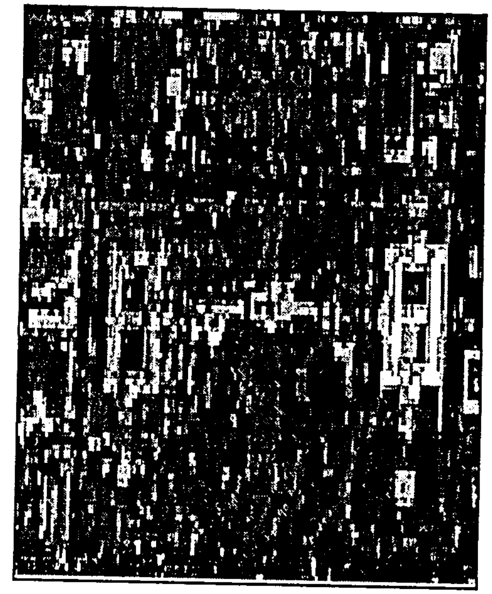


Image Understanding

Terrain modeling



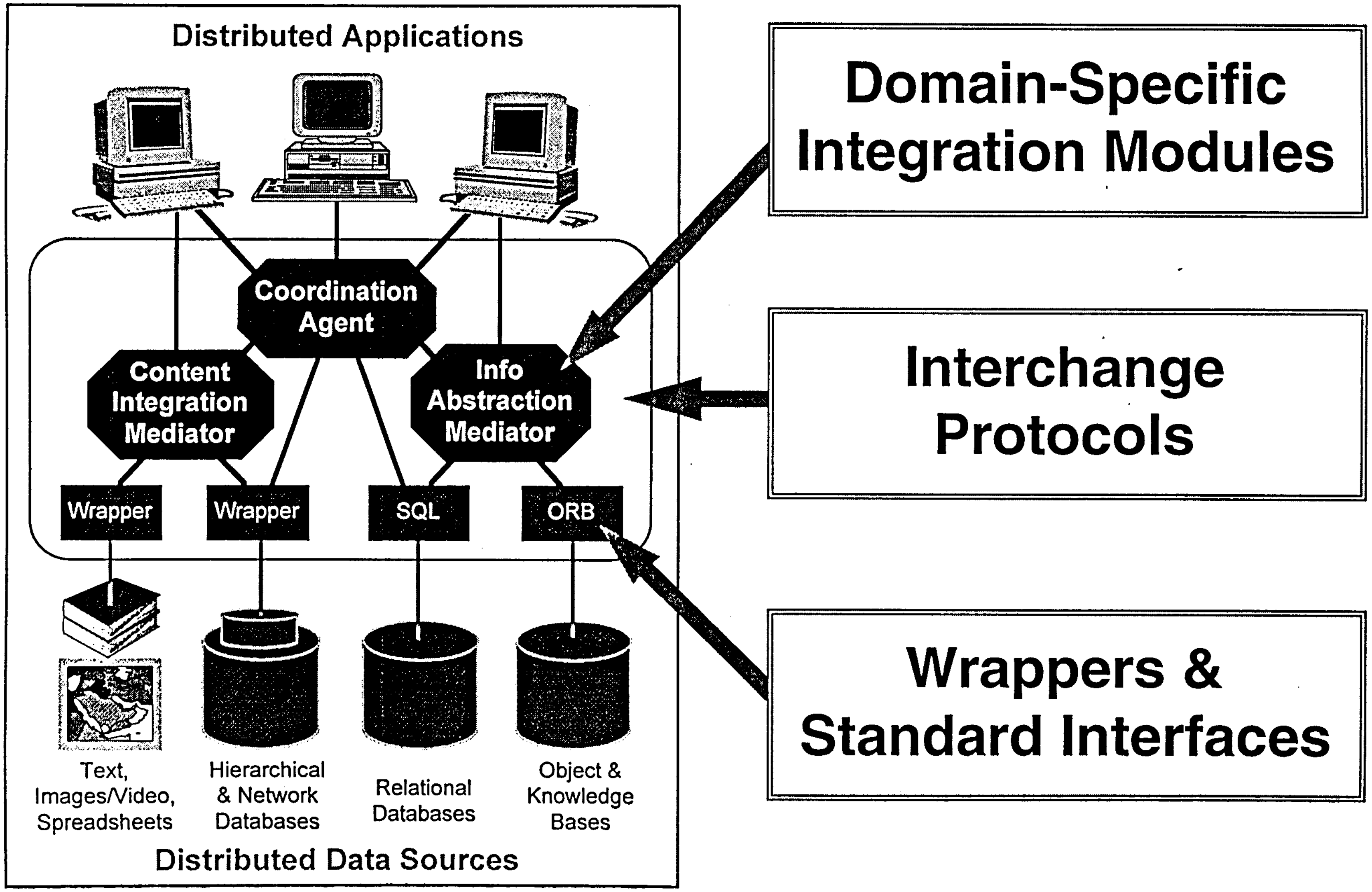
RADIUS Site modeling



Multi-spectral analysis

Development of algorithms that can interpret sensor data for use in applications for ATR, intelligence, surveillance, industrial inspection, robotics, and navigation of autonomous vehicles

I^3 Approach to Information Integration

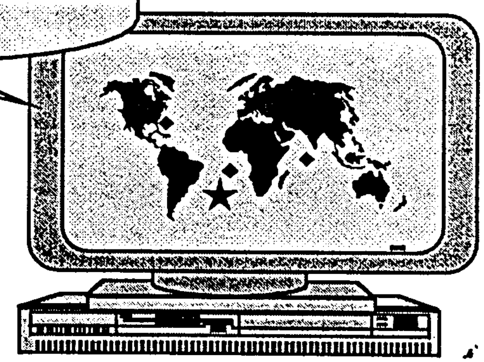


Interactive Decision Support Using Dialog

Impact: Improved military
<u>readiness, affordability, and usability</u>

Show me the <u>current position</u> of the missiles
we shipped to the the middle east
...and show me <u>where we expected them to be by now</u>

The stars show the current in-transit positions
.. the diamonds show where they were planned to be ...
<u>average shipment is behind by 18 hours</u> and the <u>mission critical shipment is 24 hours behind</u>



<u>Set-up</u> an immediate collaboration conference ..
.. include both transportation and logistic anchor desks

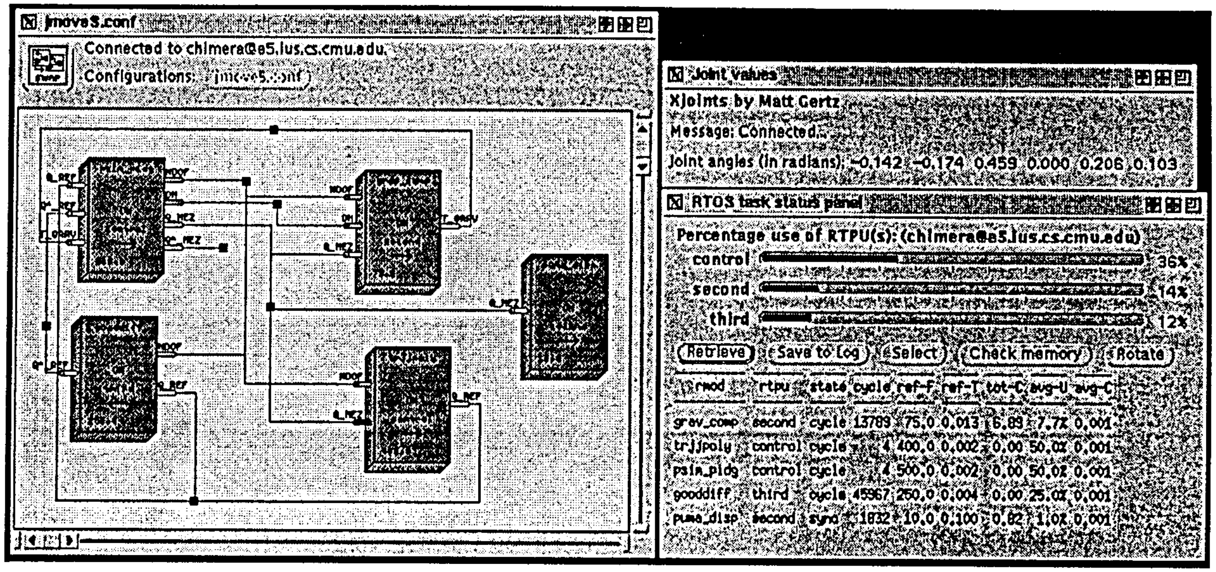
.. Oh .. and also show me the current warehouse status of any remaining missiles plus seeker heads

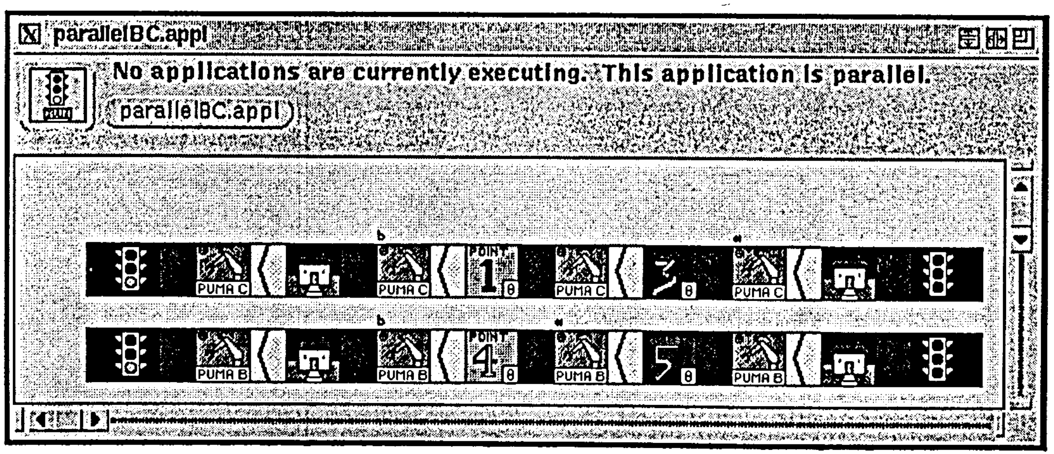
Roger: Logistics and Transportation Anchors are set-up
.. 2-way video will cost the standard rate ..
.. there will be a 2 minute wait for the warehouse info.

Real-Time Planning and Control
Real-Time Software Assembly

- Chimera RTOS supports Reusable and Reconfigurable Software

- Graphical Debugging Env for Real-Time Apps Development



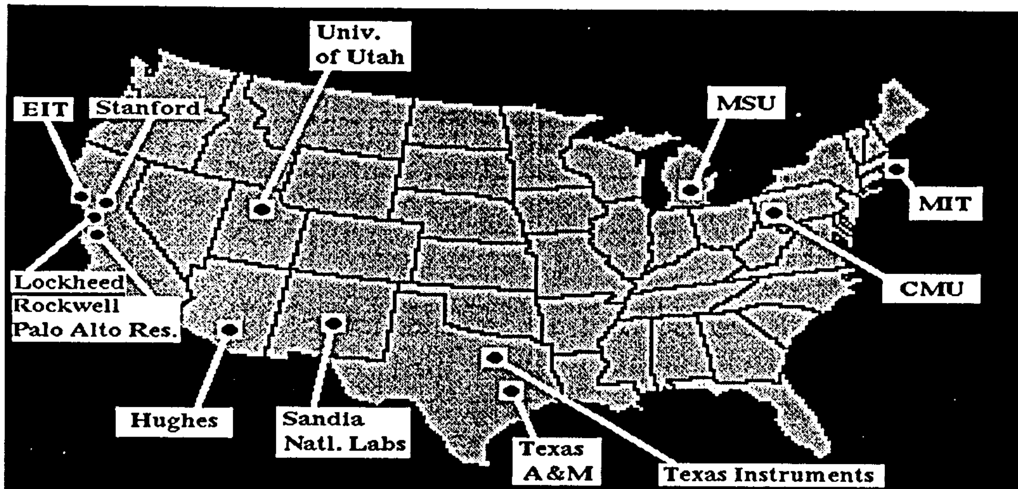


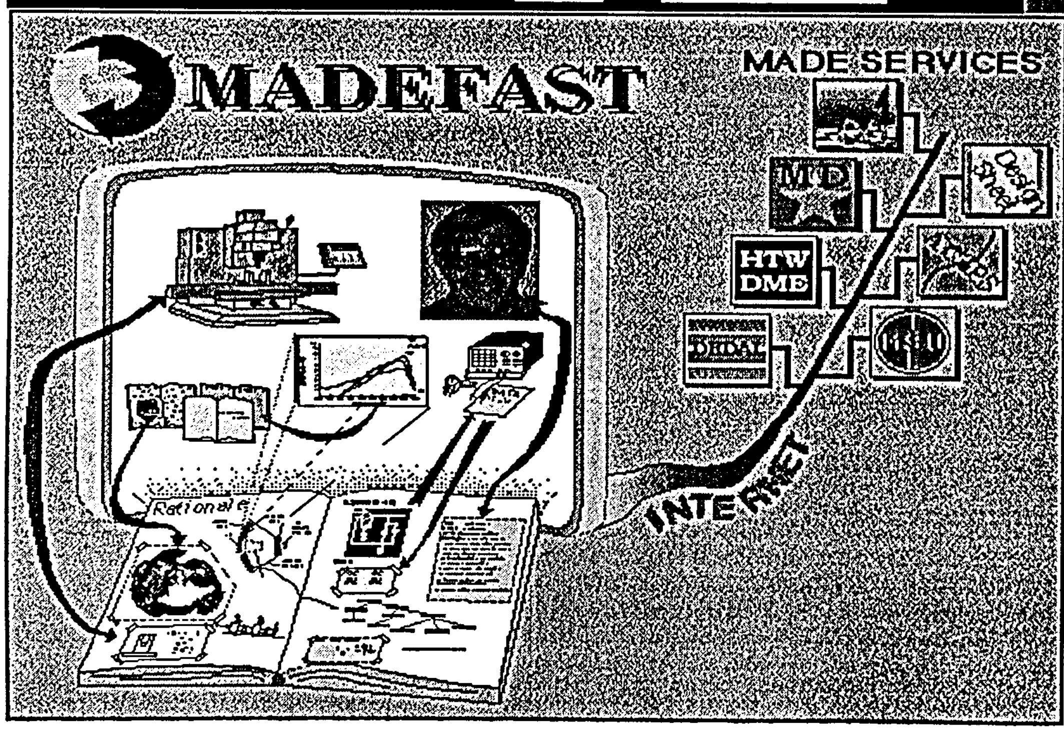
- Icons represent complex apps

- Puzzle shaped icons in Onika support rapid application development

Reconfigurable Software + HyperMedia Interface = Software Assembly

Manufacturing Automation & Design Engineering (MADE)





MADE Objectives:

- Create a collaborative design infrastructure of sufficient depth to support:
  - National network of specialists, tools, and services for designing and building electro-mech systems
  - A living project web useful for redesign, design of related products, and engineering education
  - Access to tools, services, and information with context

Technology Procurement: Current Approach

Request proposals in a technology area to satisfy a user need.

Evaluate proposals based on merit of ideas & reputation of contractor.

RESULTS AFTER A PERIOD OF TIME:

Contract work doesn't adequately cover the needs of the user.

There is no way then to warp the contracts to fit needs.

Translate Between User and Technology

Need to translate between these two worlds:

User needs $\longrightarrow$ technology requirements

Technology capabilities $\longrightarrow$ User capabilities

We use a *metrics-driven pipeline*
and
***Scenario-based Engineering Process* (SEP)**

to accomplish this.

Summary

- **The military gains significant competitive advantage through rapid, high quality planning & decision-making conducted by small distributed, dynamically-formed teams**

- **The above is made possible by affordable and evolvable software and intelligent systems**

- **This avionics & missiles workshop presents us with an excellent opportunity to better understand and clarify software engineering requirements and technology**

- **SISTO has made significant progress over the last decade both in basic research and in prototype applications**
  - **Poised to continue making paradigm-shifting contributions through our vision of "Taskable Autonomy & Cognitive Support"**

Appendix D

Evolutionary Design of Complex Systems Briefing

(Capt. J. Bartow, JAST/TM2)

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JOINT ADVANCED STRIKE TECHNOLOGY PROGRAM
U.S. NAVY U.S. MARINE CORPS U.S. AIR FORCE

EVOLUTIONARY DESIGN OF COMPLEX SYSTEMS

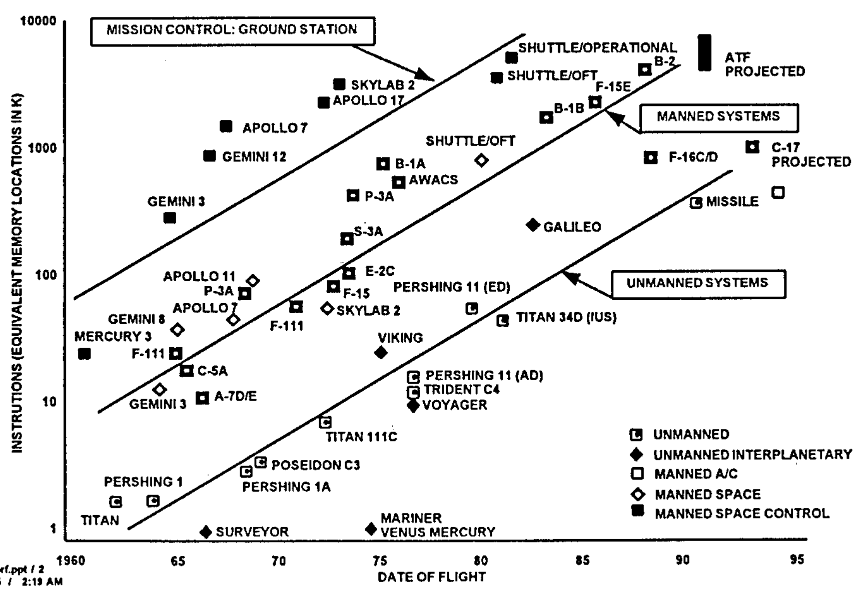
Software Productivity Consortium

31 May - 2 June 1995

Capt Jules Bartow
JAST/TM2

http://www.jast.mil
bartowj@ntrprs.jast.mil
(703) 602-7390 x6624

AUGUSTINE'S TECHFLATION - EVOLUTIONARY GROWTH WITH INCREASING COMPLEXITY



"The threat we are dealing with today is considerably reduced, maybe by as much as an order of magnitude. The irony is that the standard deviation, the variance of the threat, is up tenfold over what it was in the past. So this gives us some pause in trying to plan intelligently."

Dr. Paul Kaminski
USD (A&T)

The systems we used in Desert Storm were a result of FSD and Production programs in the 70s and 80s that provided a sufficient number of weapons and support to our trained warfighters

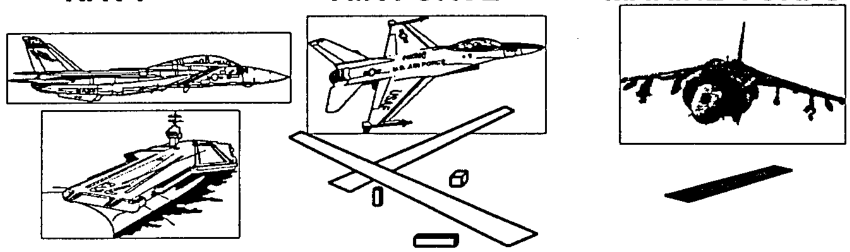
We are at the stage in JAST where the F-16, F-15, and F/A-18 were more than 20 years ago.

WE HAVE A ***COMPLEX*** PROBLEM

U. S.
NAVY

U. S.
AIR FORCE

U. S.
MARINE CORPS



AFFORDABLE
STRIKE WARFARE SYSTEMS

Joint Advanced Strike Technology Program Vision

- **A JOINT SERVICE TEAM CREATING THE BUILDING BLOCKS FOR *AFFORDABLE*, SUCCESSFUL DEVELOPMENT OF NEXT GENERATION STRIKE WEAPONS SYSTEMS**

World Wide Web address: http://www.jast.mil
Anonymous FTP Logon address: ftp.jast.mil

JAST ORGANIZATION

PROGRAM DIRECTOR
MGEN Geo Muellner, USAF

DEPUTY DIRECTOR
RADM Craig Steidle, USN

STOVL DIRECTOR
Dr Bill Scheuren, USMC

NAVAIR LIAISON
CAPT SIM AUSTIN, USN

SECURITY DIRECTOR
MAJ KEN NEWSHAM, USAF

BUSINESS & OPS MGMT
CDR "KNOB" MOSES, USN

AERO SYS CENTER LIAISON
COL BOB LYONS, USAF

REQUIREMENTS DIRECTOR
COL GEO GOODWIN, USMC

- USAF OPS RQMTS
- USAF SUPPLY RQMTS
- USN RQMTS
- USMC OPS RQMTS
- USMC SUPPLY RQMTS

TECH MATURATION DIRECTOR
DR. DON MCERLEAN
DEPUTY DIRECTOR
COL PHIL AITKEN-CADE, USAF

- SOFTWARE
- MAT'LS/STRUCTURES
- FLIGHT SYSTEMS
- PROPULSION
- AVIONICS
- WEAPONS INTEGRATION
- SUPPORTABILITY
- MFG & PRODUCIBILITY

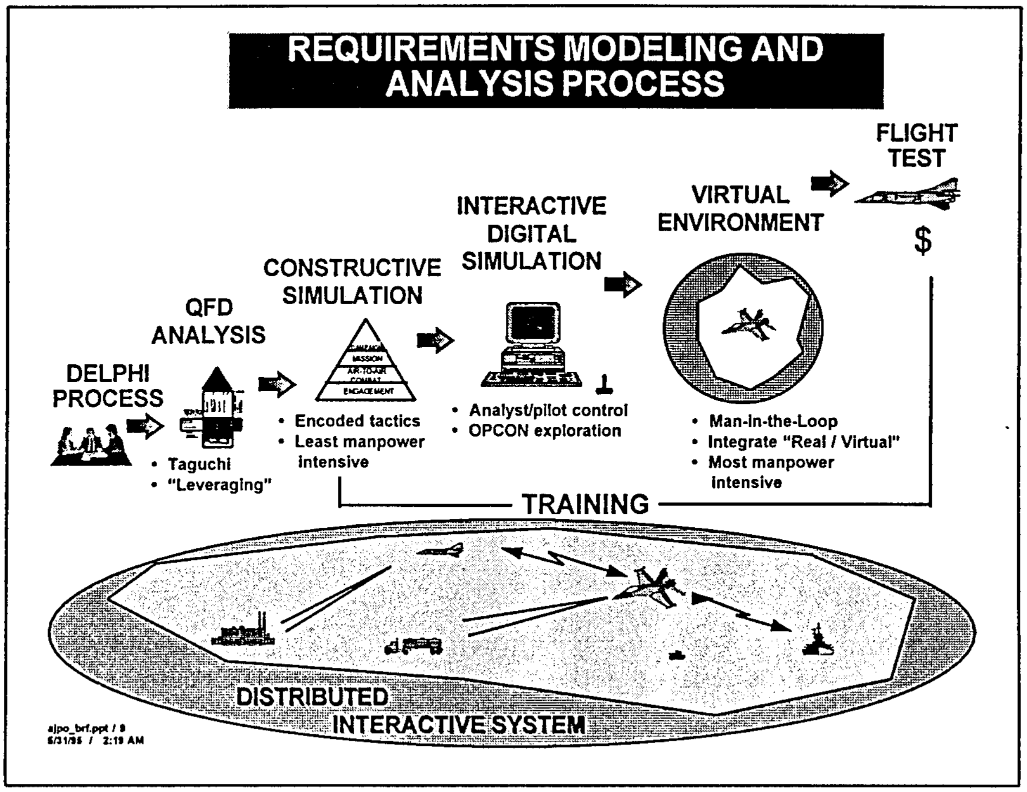
INTEGR & ANALYSIS DIRECTOR
FRED SCHWARTZ

- INTEGRATION
- INTEGR ANALYSIS
- MOD & SIM

The JAST Mission

- FACILITATE DEVELOPMENT OF FULLY VALIDATED AND AFFORDABLE OPERATIONAL REQUIREMENTS
- FACILITATE MATURATION OF LEVERAGING TECHNOLOGIES
- DEMONSTRATE LEVERAGING TECHNOLOGIES AND OPERATIONAL CONCEPTS

TRI-SERVICE FAMILY OF AIRCRAFT
33-66% LIFE CYCLE COST SAVINGS


REQUIREMENTS MODELING AND ANALYSIS PROCESS
FLIGHT TEST
VIRTUAL ENVIRONMENT
INTERACTIVE DIGITAL SIMULATION
CONSTRUCTIVE SIMULATION
QFD ANALYSIS
DELPHI PROCESS
$
• Taguchi
• "Leveraging"
• Encoded tactics
• Least manpower intensive
• Analyst/pilot control
• OPCON exploration
• Man-in-the-Loop
• Integrate "Real / Virtual"
• Most manpower intensive
TRAINING
DISTRIBUTED INTERACTIVE SYSTEM
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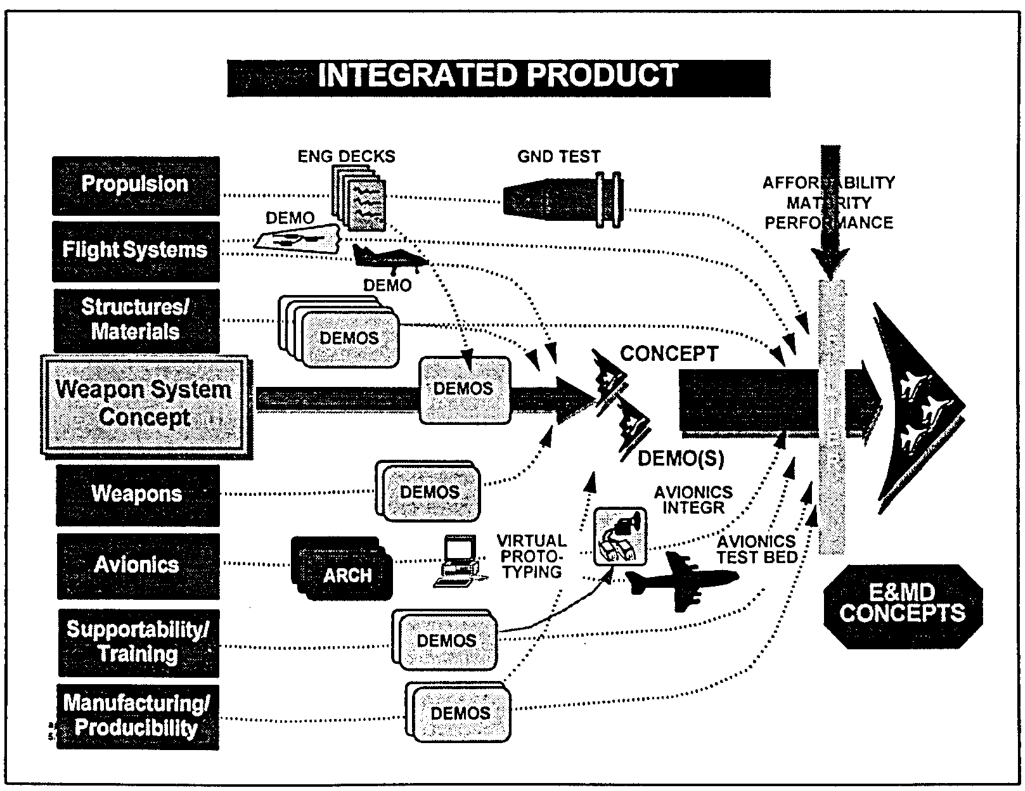
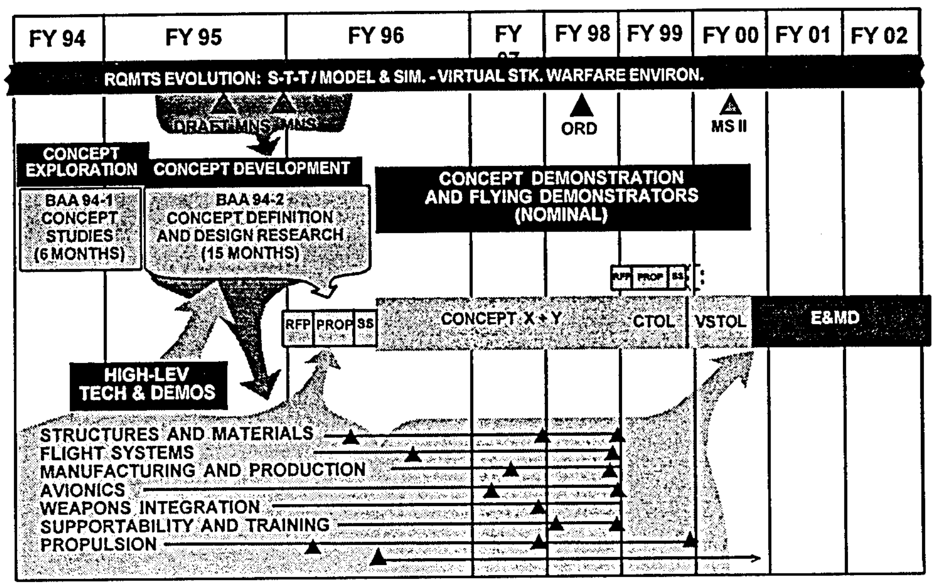

INTEGRATED PRODUCT
Propulsion
Flight Systems
Structures/ Materials
Weapon System Concept
Weapons
Avionics
Supportability/ Training
Manufacturing/ Producibility
ENG DECKS
GND TEST
DEMO
DEMO
DEMOS
DEMOS
DEMOS
ARCH
VIRTUAL PROTO-TYPING
DEMOS
DEMOS
CONCEPT
DEMO(S)
AVIONICS INTEGR
AVIONICS TEST BED
AFFORDABILITY
MATURITY
PERFORMANCE
E&MD CONCEPTS

JAST PROGRAM SCHEDULE



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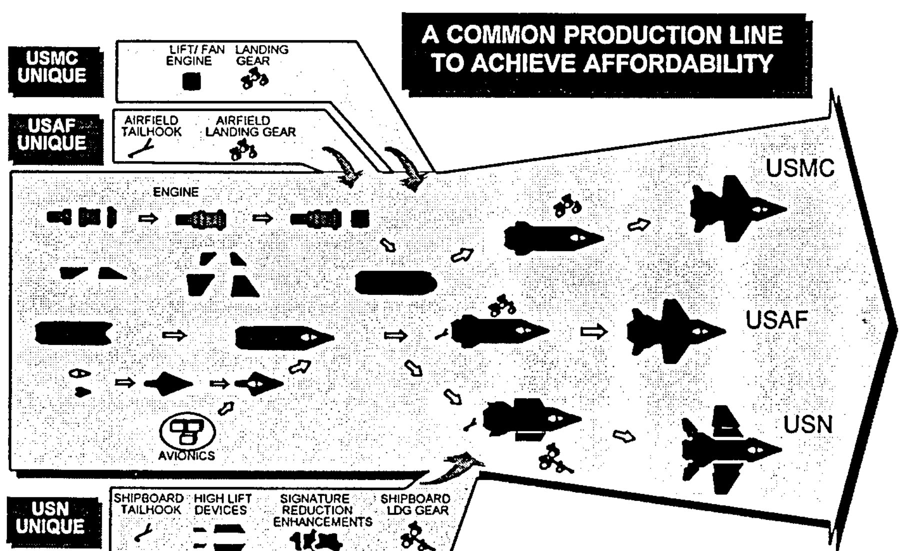
BAA 94-1 STUDIES

COMPANY	SUBJECT AREA	AMOUNT
• Lockheed Ft Worth, TX	Leveraging Affordability Concept	$ 1,993,837
• Boeing Defense & Space Group, Seattle, WA	Modular Multi-Service Air Frame	$ 2,230,638
• Northrop Corp Pico Rivera, CA	Virtual Strike Environment	$ 495,291
• McDonnell Douglas Aerospace St Louis, MO	Affordable Off-Board Architecture	$ 575,000
• McDonnell Douglas Aerospace St Louis, MO	Joint Strike Warfare Concept	$ 1,686,000
• Honeywell, Inc. Minneapolis, MN	Affordable Next Generation Avionics	$ 99,936
• Hughes Missile Systems Co. Canoga Park, CA	Cost-Effective Weapon Carriage Options	$ 291,678
• Litton Amecon College Park, MD	Sensor Integration Trades & Architecture	$ 530,000
• Northrop Corporation Pico Rivera, CA	Joint Strike Aircraft Concept Exploration	$ 688,756
• Grumman Aerospace Bethpage, NY	JAST Affordability Studies	$ 330,111
• Cambridge Research McLean, VA	Virtual Strike Environment Architecture	$ 825,605
• McDonnell Douglas Aerospace St Louis, MO	Affordable Weapon Integration Study	$ 720,000

TECHNOLOGY MATURATION RESULTS

- **WEAPONS INTEGRATION**
  - EXTERNAL CARRIAGE DOES NOT MEET REDUCED SIGNATURE NEEDS FOR FIRST DAY SURVIVABILITY
  - GREATER PRECISION ENABLES SMALLER WEAPON LOADS, SMALLER AIRCRAFT AND THEREFORE LOWER LCC
- **AVIONICS**
  - ADVANCED TECHNOLOGY OPEN SYSTEM AVIONICS CAN REDUCE LCC 8% -12%
  - EXPLOITATION OF OFF-BOARD ASSETS CAN REDUCE LCC 4% - 11%
    - » HOWEVER, USE IS CONSTRAINED BY COVERAGE
- **SUPPORTABILITY**
  - ADVANCED DIAGNOSTICS CAN REDUCE SPARES UP TO 40% AND MAINTENANCE MAN-HOURS UP TO 25%
  - LO IS A MAINTENANCE MAN-HOUR DRIVER

CURRENT PROGRAM FOCUS A FAMILY OF THREE AIRCRAFT



BAA 94-2 ACTIVITIES

COMPANY	SUBJECT AREA	AMOUNT
• Boeing	Tri-Service Weapon System Concept	$ 27,614,120
• McDonnell Douglas Aerospace	Joint Strike Weapon System Concept Definition and Design Research	$ 28,193,501
• Northrop Grumman Corp	Joint Strike Weapon System Concept Definition and Design Research	$ 24,085,919
• Lockheed	Joint Strike Weapon System Concept Definition and Design Research	$ 19,900,000
• Boeing	Avionics Virtual Systems Engineering and Prototyping	$ 2,288,774
• Northrop Grumman Corp Hughes, TRW & Research Triangle Institute	Avionics Virtual Systems Engineering and Prototyping	$ 2,125,190
• Texas Instrument Honeywell, Litton Amecom	Avionics Virtual Systems Engineering and Prototyping	$ 2,464,392
• Lockheed (FW)	On-Board Off-board Information Fusion	$ 2,016,004
• Lockheed (FW)	Structurally Integrated Reconfigurable Multi-function Apertures (SIRMA) Study	$ 441,938
• Hughes Boeing	Wideband Integrated Forebody (IFB) Technology Maturation	$ 1,310,174
• TRW	Advanced Strike Integrated Diagnostics (ASID)	$ 2,004,219
• Unisys McDonnell Douglas Aerospace	Scaleable Multiprocessing System (SMPS)	$ 1,210,000
• Westinghouse	Affordable Rf/If Packaging	$ 314,943

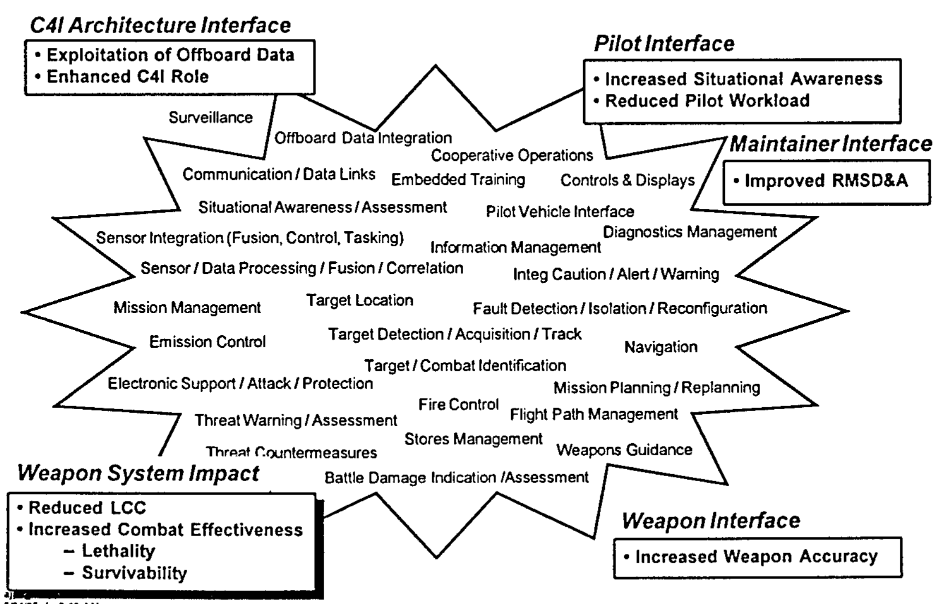
BAA 94-2 ACTIVITIES

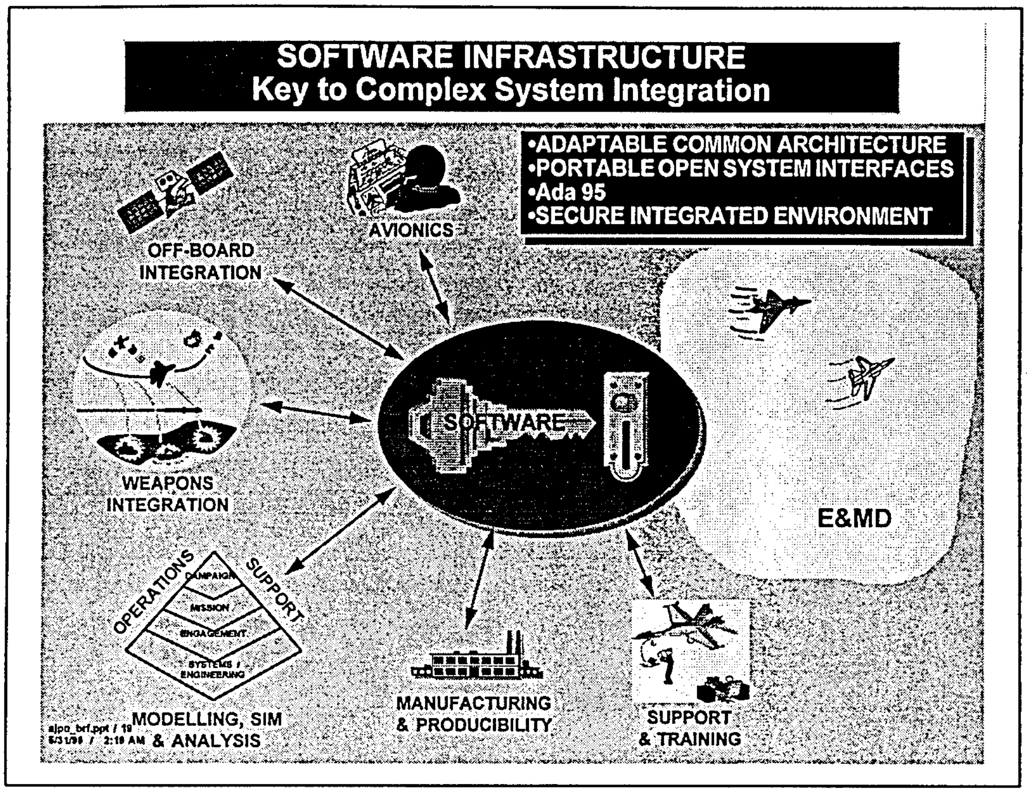
COMPANY	SUBJECT AREA	AMOUNT
• Martin Marietta	JAST Affordable Modular EO/IR Sensor Subsystem	$ 535,755
• Rockwell Intl (Collins)	RF Technology Maturation Proposal	$ 719,484
• Hughes	JAST Secure Avionics Architecture Concept Development	$ 291,980
• D. Gustavson	Compare Performance of Proposed SCI/RT Mechanisms	$ 50,000
• P&W	JAST Propulsion System Demos	$ 5,448,143
• GE/Allison	JAST Maturing Technologies in an Engine Environment Low Cost Nozzles for Enhanced Strike Effectiveness	$ 3,657,288
• Rockwell Lockheed General Electric	Turbocooler Engine Demonstration for Flexible Thermal Management Fluidic Thrust Vectoring Nozzle Study	$ 278,051
• Boeing Dassault	JAST Multi-service Common Airframe	$ 1,740,920

BAA 94-2 ACTIVITIES

COMPANY	SUBJECT AREA	AMOUNT
• ASI	Spreadsheet Methodology for Tradeoff Analysis	$ 346,553
• Aerodyne	Advanced Survivability Model for Strike Warfare	$ 250,920
• Geodynamics	Off-Board MS&A Concept Definition and Design Research	$ 486,659

AVIONICS FUNCTIONS & INTERFACES - COMPLEXITY




SOFTWARE INFRASTRUCTURE
Key to Complex System Integration
•ADAPTABLE COMMON ARCHITECTURE
•PORTABLE OPEN SYSTEM INTERFACES
•Ada 95
•SECURE INTEGRATED ENVIRONMENT
AVIONICS
OFF-BOARD INTEGRATION
SOFTWARE
WEAPONS INTEGRATION
E&MD
OPERATIONS
SUPPORT
CAMPAIGN
MISSION
ENGAGEMENT
SYSTEMS / ENGINEERING
MODELLING, SIM & ANALYSIS
MANUFACTURING & PRODUCIBILITY
SUPPORT & TRAINING
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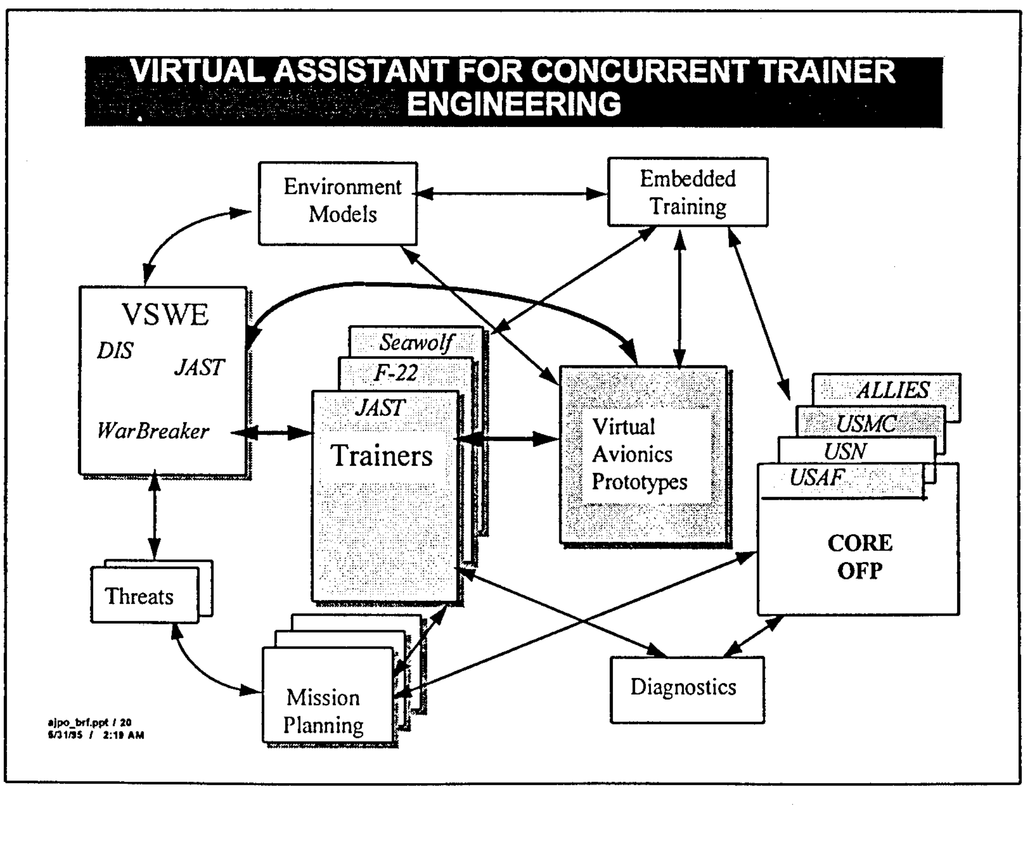
VIRTUAL ASSISTANT FOR CONCURRENT TRAINER ENGINEERING
Environment Models
Embedded Training
VSWE
DIS
JAST
WarBreaker
Seawolf
F-22
JAST
Trainers
Virtual Avionics Prototypes
ALLIES
USMC
USN
USAF
CORE OFP
Threats
Mission Planning
Diagnostics
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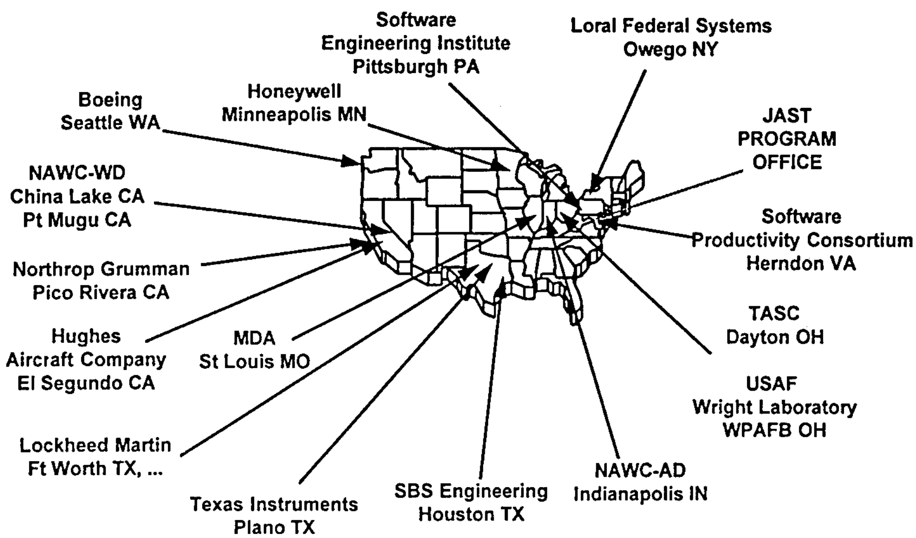
SOFTWARE PROJECT TEAM ORGANIZATION



LEVERAGING, MATURING, and DEMONSTRATING ARPA and USAF/ NAVY LAB AFFORDABLE TECHNOLOGIES

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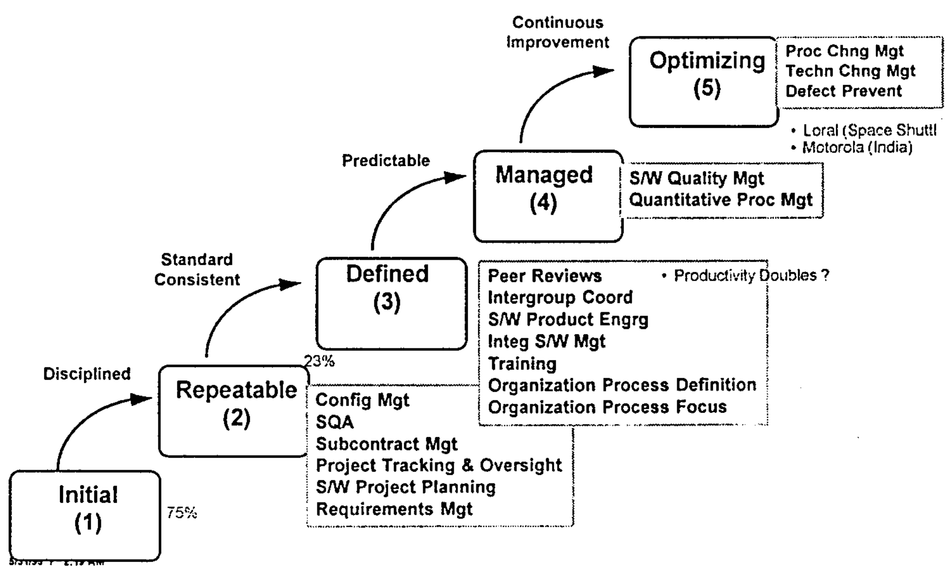
Capability Maturity Model (Software Engineering Institute)



Software Support For Generic Strike Fighter of the 70s and 80s

- **Software Evolution**
  - Initially Designed for Air to Air Role
  - Air to Ground Missions added over Time
  - Digitized Engine Controllers, Flight Controls, and Diagnostic Software Added
- **New Hardware Baseline Every Five (5) Years**
  - Nav
  - Defensive Systems
  - Radar
  - Weapons
- **2 years / 5 software updates to resolve software issues**
- **Normal Software Updates on a 18-24 Month Schedule**
  - Multiple Configurations - H/W dash numbers, Missionized variants, FMS
  - Bottlenecks in Lab
  - Entire Maint Cycle (Defn, Analysis, Design, Code, Test, Distr) 36-44 Months
    - » 6-10 Months to Define Requirement
    - » 9 Months to Award Contract

John White, SM-ALC F-22 SPO
17 Jun 94

Software Support For Generic Strike Fighter of the 70s and 80s

- **Little Software Reuse when Hardware Upgraded**
- **Software Changes in Block Cycle Limited**
  - Funds
  - Schedule
  - Increased Integration and Test Requirements
- **Focus of Changes**
  - PVI (60%)
  - Stores Additions
  - Launch Envelope Improvements
  - Radar Improvements
  - ECM/ECCM
  - ID Capabilities & Improvements
- **Changes only with Hardware**
  - Landing Gear, Anti-Skid, Flight Controls
- **Infrequent Changes**
  - INS, ADC, Digital Storage Units

John White, SM-ALC F-22 SPO
17 Jun 94

Software Support For Generic Strike Fighter of the 70s and 80s

- Organic Support 5-8 Years after FCA/PCA in Spite of PMD
- Trainer Software
  - Different Acquisition System than OFP
  - 2 Years to Reverse Engineer OFP and Forward Engineer into Trainer
- Metrics & Project Estimates ROM'd
  - Integration & Test Typically Several Months Late & Over Budget
- LESSONS LEARNED
  - COMMUNICATIONS PROBLEMS BIGGEST IMPEDIMENT
  - PLAN FOR MULTIPLE CONCURRENT DEVELOPMENT EFFORTS
  - TECHNOLOGY INSERTION ASAP
  - MEMORY AND THROUGHPUT SHOT BY FIFTH BLOCK CHANGE
  - OFP CHANGES CREATE MAJOR SIMULATION & STIMULATION CHANGES
  - DESIGN RATIONALE MORE IMPORTANT THAN FORMAL DOCUMENTATION

Software Support For Generic Strike Fighter of the 70s and 80s

- LESSONS LEARNED (Cont'd)
  - COMPREHENSIVE SIMULATIONS HAVE RAPID RETURN ON INVESTMENT
  - LABS NEED SAME PRIORITIZATION FOR SPARES AND REPLACEMENT PARTS
  - CO-LOCATED INTEGRATION AND FLIGHT TEST FACILITIES REDUCE FLIGHT TEST COSTS WHILE IMPROVING SCHEDULE ADHERENCE AND REQUIREMENTS COMMUNICATION

SECURITY REQUIREMENTS DRIVING SOFTWARE SIZE/COMPLEXITY

DoDReg 5200.1-R Internal Classification Marking

D: Minimal Protection

C: Discretionary Protection No Trusted Labels - Labeled @ system high

B: Mandatory Protection - Trusted Computing Base

Limited Access, Controlled, Compartmented

- **B1:** System High may not label sensitivity correctly - Manual intervention req'd
- **B2:** Covert channels addressed, formal security policy to all objects in system, Protection critical vs non-critical elements, Capture non-intentional errors
- **B3:** Minimum Complexity, Security Management by Security, Mediate access to all elements, system recovery procedures, signal security events

A: Formal Design Specs & Verification + Better CM

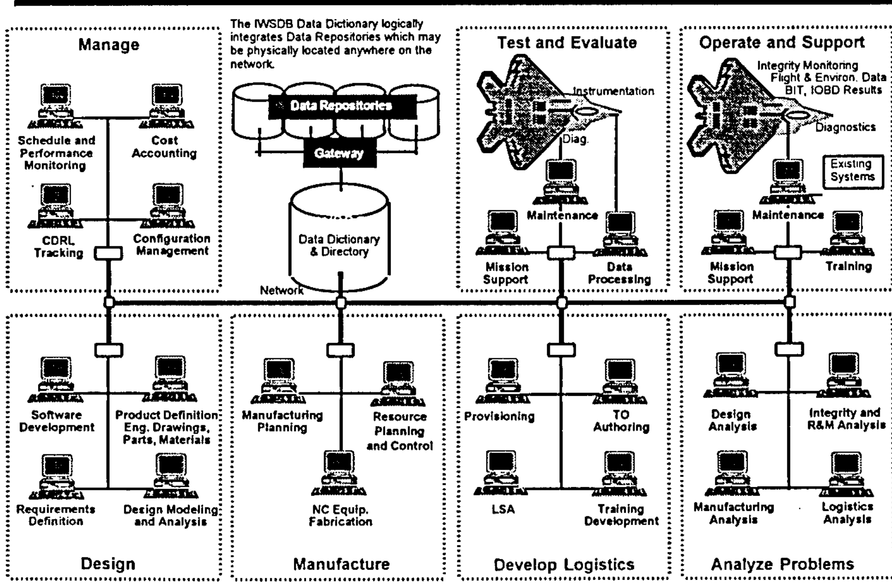
FAULT TOLERANT REQUIREMENTS DRIVING SOFTWARE SIZE/COMPLEXITY

- REQUIREMENTS ERRORS
  - NEW SYSTEMS
  - CONFLICTING, MISSING, TBDs, PVI, VOLATILITY
- DEVELOPMENT ERRORS
  - X ERRORS PER KSLOC
  - BIT BUCKETS
- DATA ERRORS
  - NOISE
  - FILE CORRUPTION
- HARDWARE ERRORS
  - REDUNDANCY
  - DIAGNOSTICS
  - DYNAMIC RECONFIGURATION
- OPERATOR INDUCED ERRORS
  - PILOT INDUCED OSCILLATIONS
  - REGIME OF ALL POSSIBILITIES

INFORMATION REQUIREMENTS DRIVING SOFTWARE SIZE/COMPLEXITY

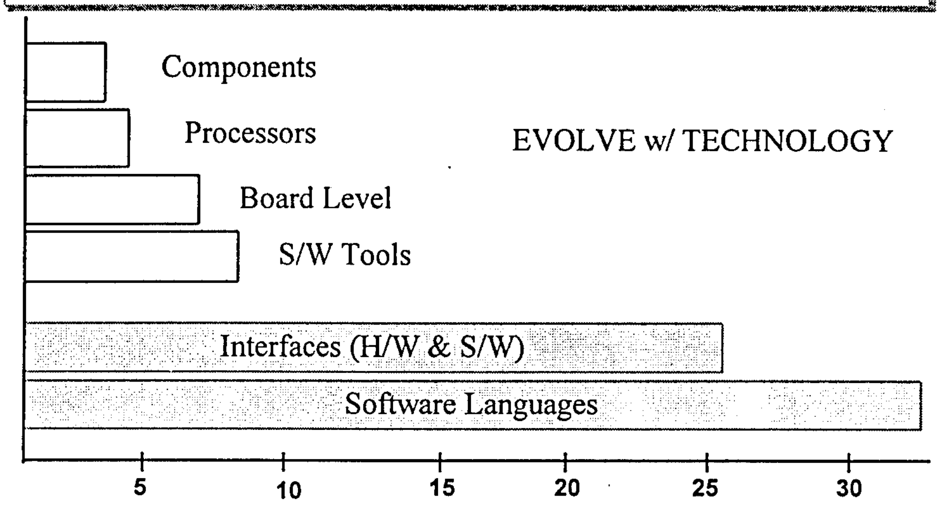
- THOUSANDS OF INTERFACES
- THOUSANDS OF REQUIREMENTS
- HUNDREDS OF SOFTWARE DEVELOPERS
- COMMUNICATIONS

Concept of an Intelligent Integrated Software/System Engineering Environment



TIME TO OBSOLESCENCE

SET FOUNDATION IN LONG LIVED STANDARDS.
DESIGN TO ALLOW OTHER AREAS TO EVOLVE

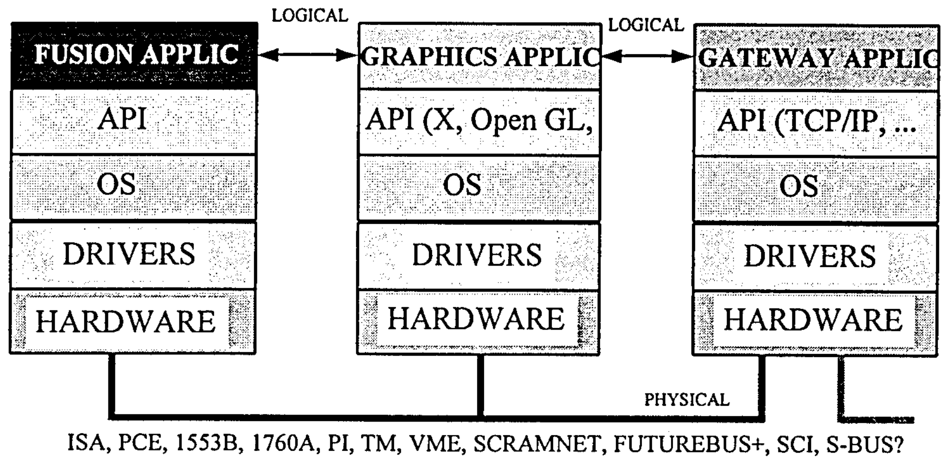


AVIONICS INTEROPERABILITY

- EACH AVIONICS VENDOR HAS UNIQUE AVIONICS OPERATING SYSTEMs
- LEGACY SYSTEMS CONSTRAIN ADOPTION OF NEW STANDARDS
- 2X IMPROVEMENT IN HARDWARE EVERY 18 MONTHS
- HARDWARE OBSOLETE IN 3-5 YEARS
- NEW APPLICATIONS AND THEIR INTERFACES UNDEFINED

CDI
DIGITAL
HARRIS
HONEYWELL
HUGHES
LORAL
IBM
INTEL
LITTON
LOCKHEED ~~SANDERS~~
MARTIN ~~MARIETTA~~
MOTOROLA
RAYTHEON
ROCKWELL COLLINS
TELEDYNE
~~UNISYS~~
TEXAS INSTRUMENTS
VITRO
TRW
WESTINGHOUSE

OPEN SYSTEM INTERFACES

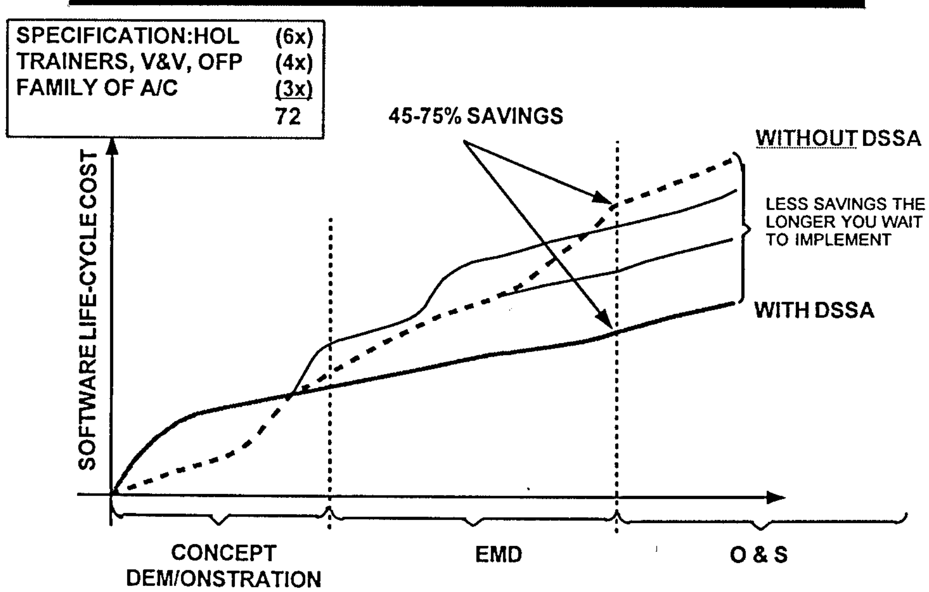


REQUIRING "OPEN SYSTEM STANDARDS" IS ONE THING.

CHOOSING, IMPLEMENTING, AND INTEGRATING THEM IS ANOTHER

UNCLASSIFIED

DOMAIN SPECIFIC S/W ARCHITECTURES: AFFORDABILITY MULTIPLIERS



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UNCLASSIFIED

IMMATURE AREA OPPORTUNITIES RIPE FOR INVESTMENT

- **SIGNAL PROCESSORS, FIRMWARE**
  - 60 - 70% OF PROCESSING
  - INCONSISTENT PROPRIETARY INTERFACES
  - NO OPERATING SYSTEM EQUIVALENT TO POSIX/DOS/WINDOWS
  - RASSP PROVIDES TOOLS FOR APPLICATION SPECIFIC H/W
- **DSSA FOR OTHER THAN FLIGHT CONTROLS**
  - MISSION MANAGEMENT FUNCTIONS
  - MULTI-SENSOR CORRELATION & PRESENTATION
  - MODELING, SIMULATION, STIMULATION
- **COLLABORATIVE ENVIRONMENTS**
  - CAPTURING, STORING, AND RETRIEVING TERABYTES OF INFORMATION
  - IMPRECISE AS WELL AS FORMAL QUERIES
- **HYPERLINKS IN CODE**
  - LINKS TO DESIGN RATIONAL & DOMAIN INFORMATION

Appendix E

Evolutionary Design of Complex Software

(Dr. H. Shrobe, ARPA)

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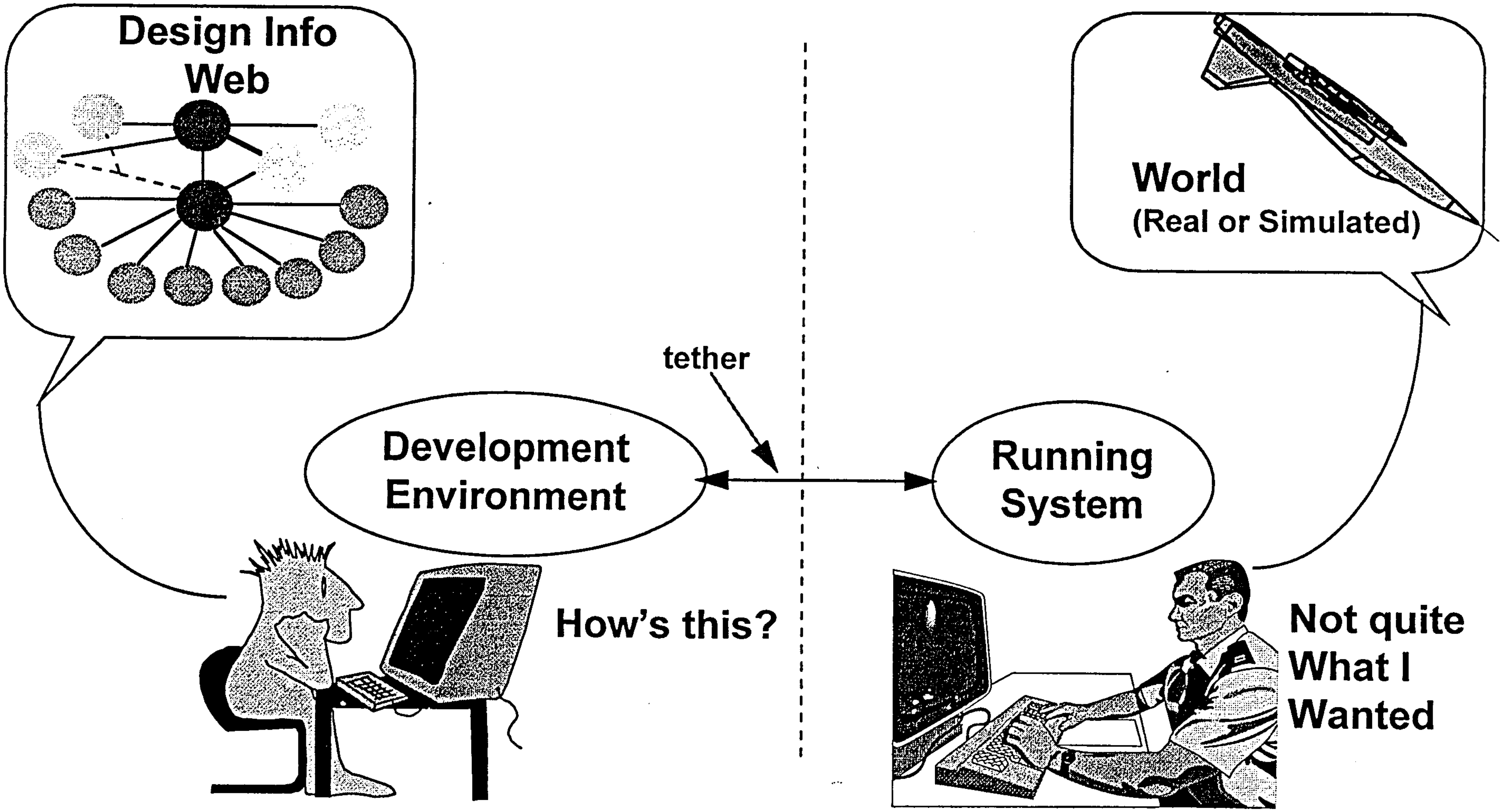
The Vision: User Centered Evolutionary Design



Long Term Roadmap

1992 — 1997

"MegaProgramming":
Systematic, Architecture-Driven Design
Families, Process, Architecture & Reuse, Composition, Environments
STARS Application Demonstrations

Winding Down

1996 — 2000

Evolutionary Design:
Incremental, Rationale Driven,
User Centered Continuous Improvement
Design Webs, Synthesis, Dynamic Languages, Predictability
EDCS Application Demos

Starting Up

1998? — 20xx?

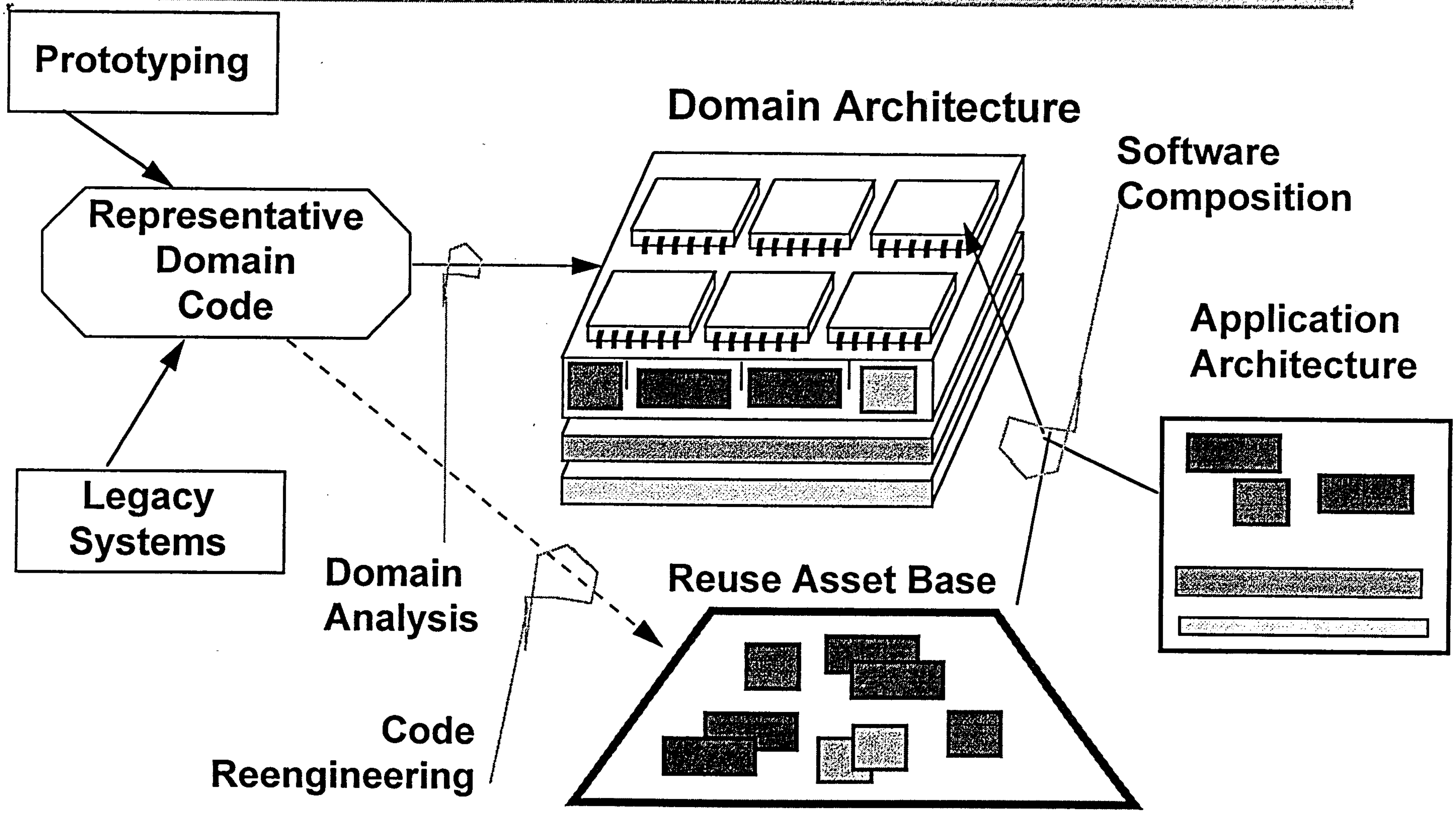
User Driven Evolution
Self Descriptive, Knowledge Based
End User Field-Modifiable
Design Knowledge Bases, Automated Resynthesis
??

Blue Sky

Current Program Vision: Cost Reduction through Architecture-Driven Reuse

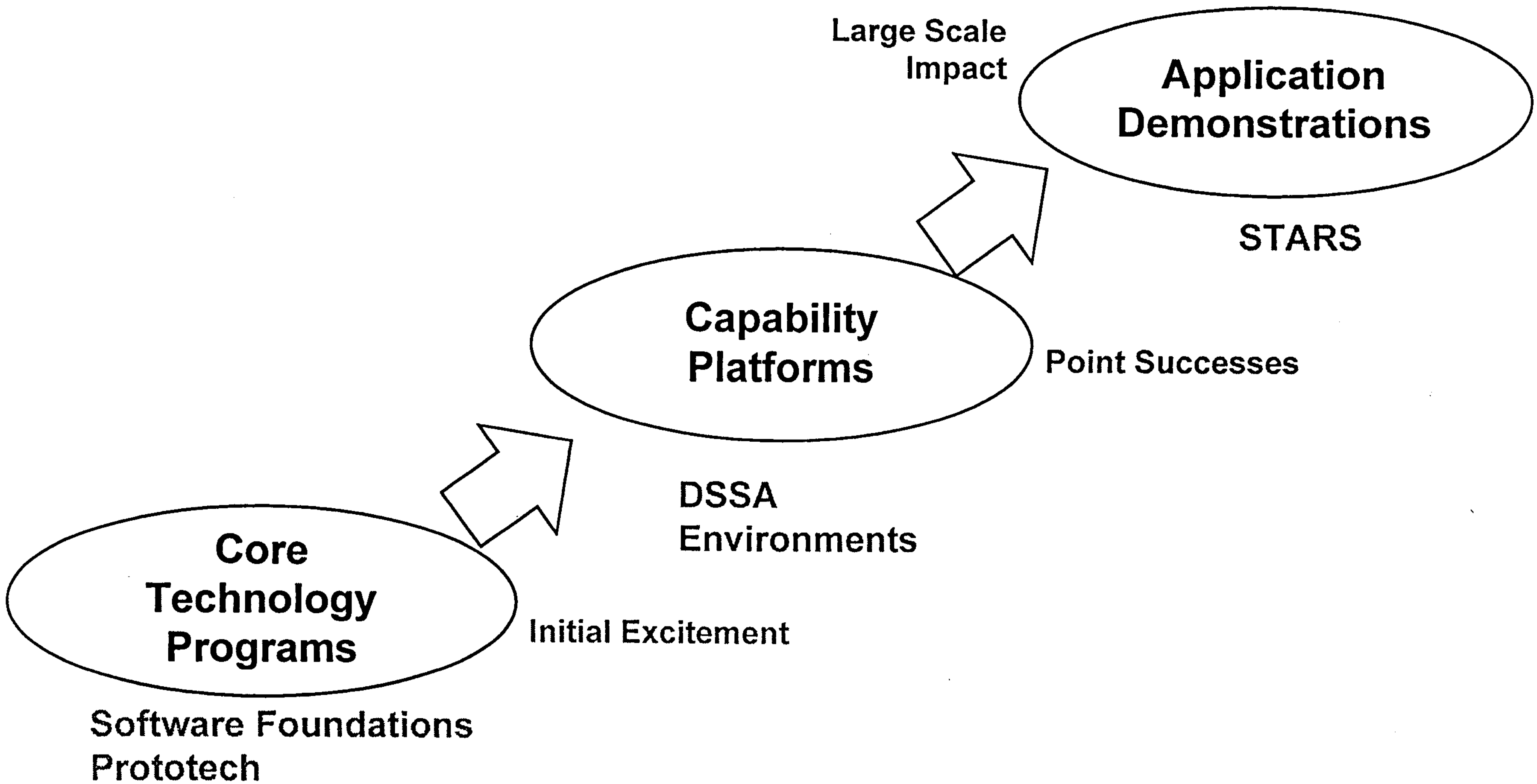
- Applications within Domain Share common services
  - Service Layers Account for Bulk of Code
- Architecture of Service Layers enables reuse
- Systematic Process needed to discover (new domain) or recover (existing domain) this architecture.
- Formalization of Architecture enables automation for synthesis, analysis, composition.
- Integrated Software Engineering Environment needed to support approach.

Program Relationship

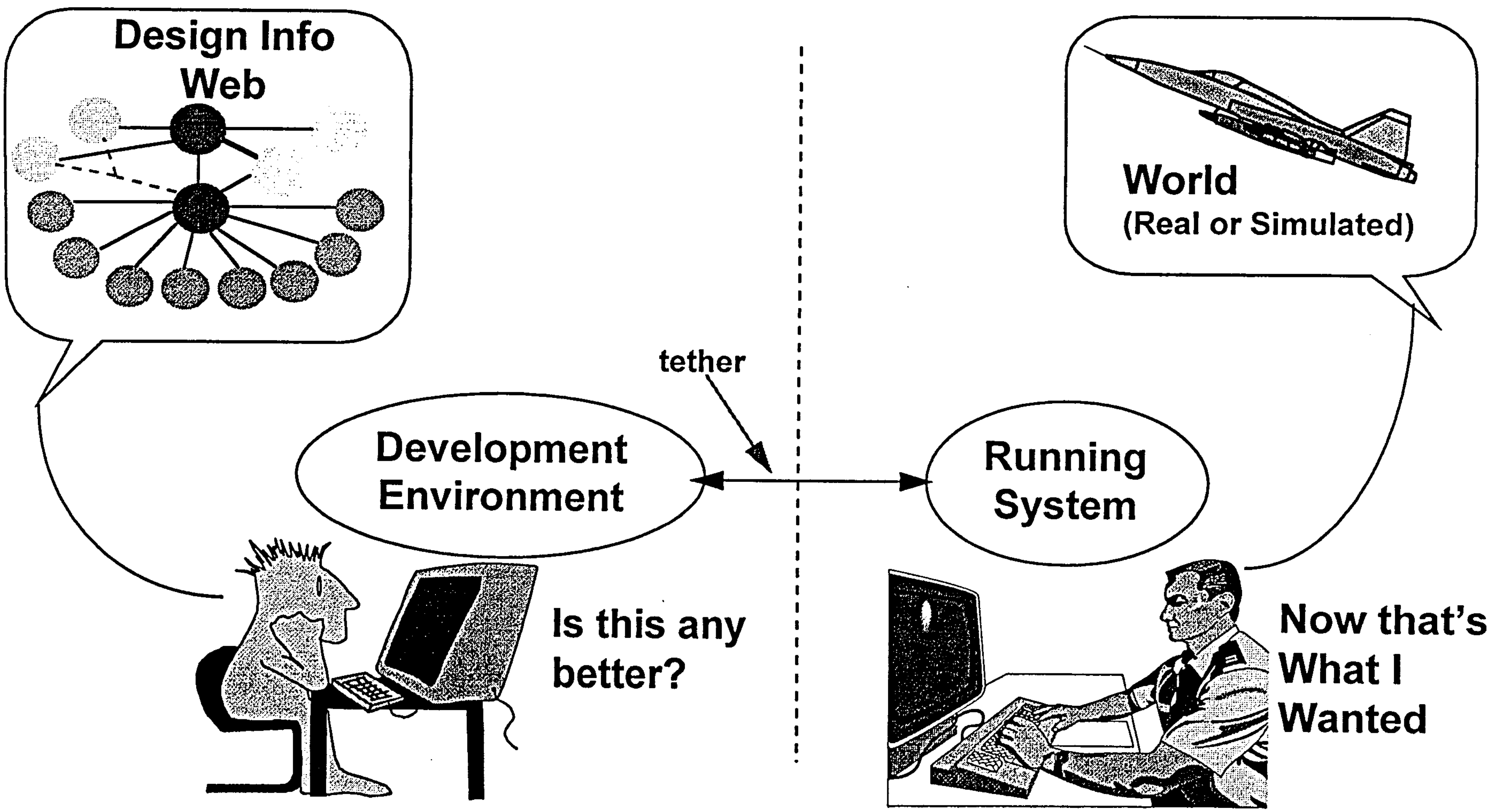


Integrated Environment

Technology Pipeline



The Vision: User Centered Evolutionary Design



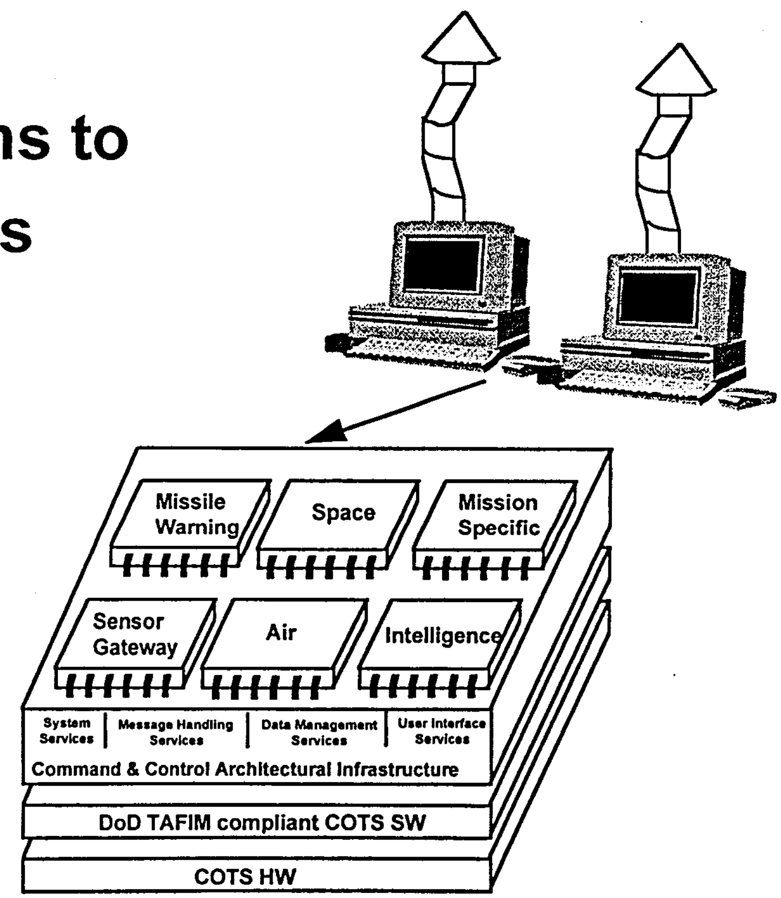
New Technology Focus: Evolutionary Design of Complex Software

- The Paradigm Shift
  - From Static, Stovepipe Systems
  - to Evolvable Application Families
- HyperProgram Design Webs
- Three Technical Thrusts

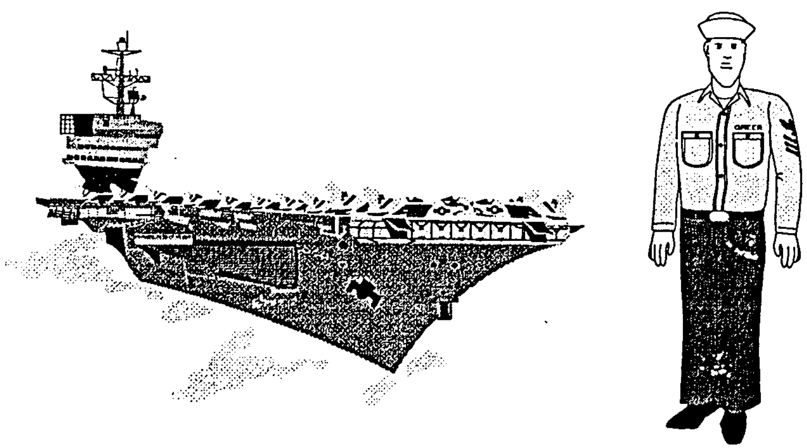
Evolutionary Design

THE PARADIGM SHIFT:

- **From Static Stovepipe Systems to Evolvable Application Families**
  - -Lower entry barriers
  - -Ease of use



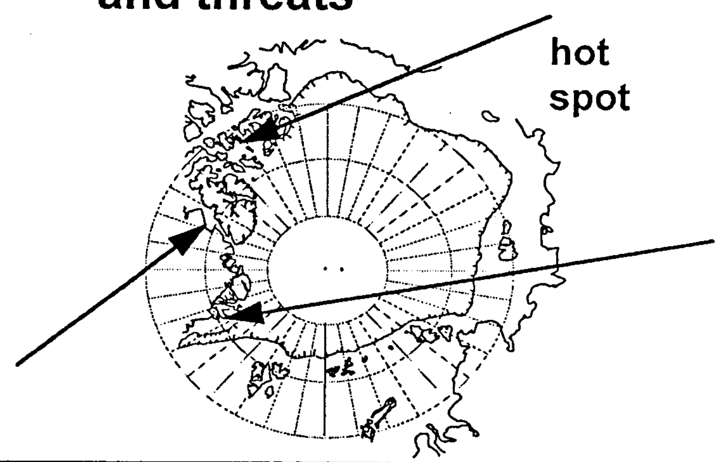
Long Lived Systems in a Volatile World



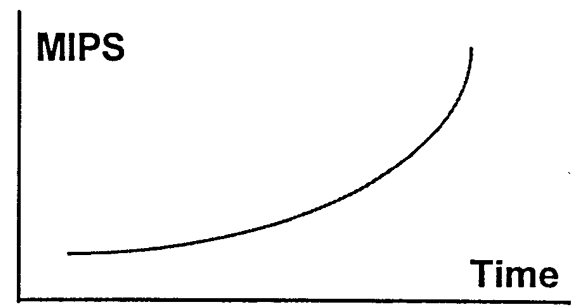
The Ship is older than the average age of the men who serve on it

-- Nova Show "Carrier"

changing world situation and threats



Rapidly Expanding Technology



Slaying The "Software Maintenance" Dragon

- Software maintenance dominates life cycle cost.
- That's OK: It's what we intended.
- It's not OK: We've misunderstood the problem
- The right kinds of tools and design environment will make a big difference

The “Maintenance” fallacy

- Maintenance is treated as an afterthought

- But “maintenance” activities are really “evolutionary design” activities

  - Continuous product improvement
  - Adaptation to Specific Users’ Needs
  - Upgrading shared software substrate when adding a new application to family
  - Major feature upgrades

Towards Affordable, Evolvable Application Families

Past

- Requirements are fixed
- Applications are Isolated
- Architecture and code separate
- Tools emphasize "front end system's analysis"
- No Shared Substrate
- Design is followed by maintenance
- Premature Optimization
- Implementation is static, compiles in design decisions to save resources
- Design Info discarded

Future

- Requirements change
- Applications in Families
- Architecture and code integrated & evolve together
- Tools support whole system lifetime
- Evolving Substrate
- Design and maintenance are a single activity
- Late Binding
- Implementation and environment use resources to support evolution.
- Design Info preserved to guide evolution

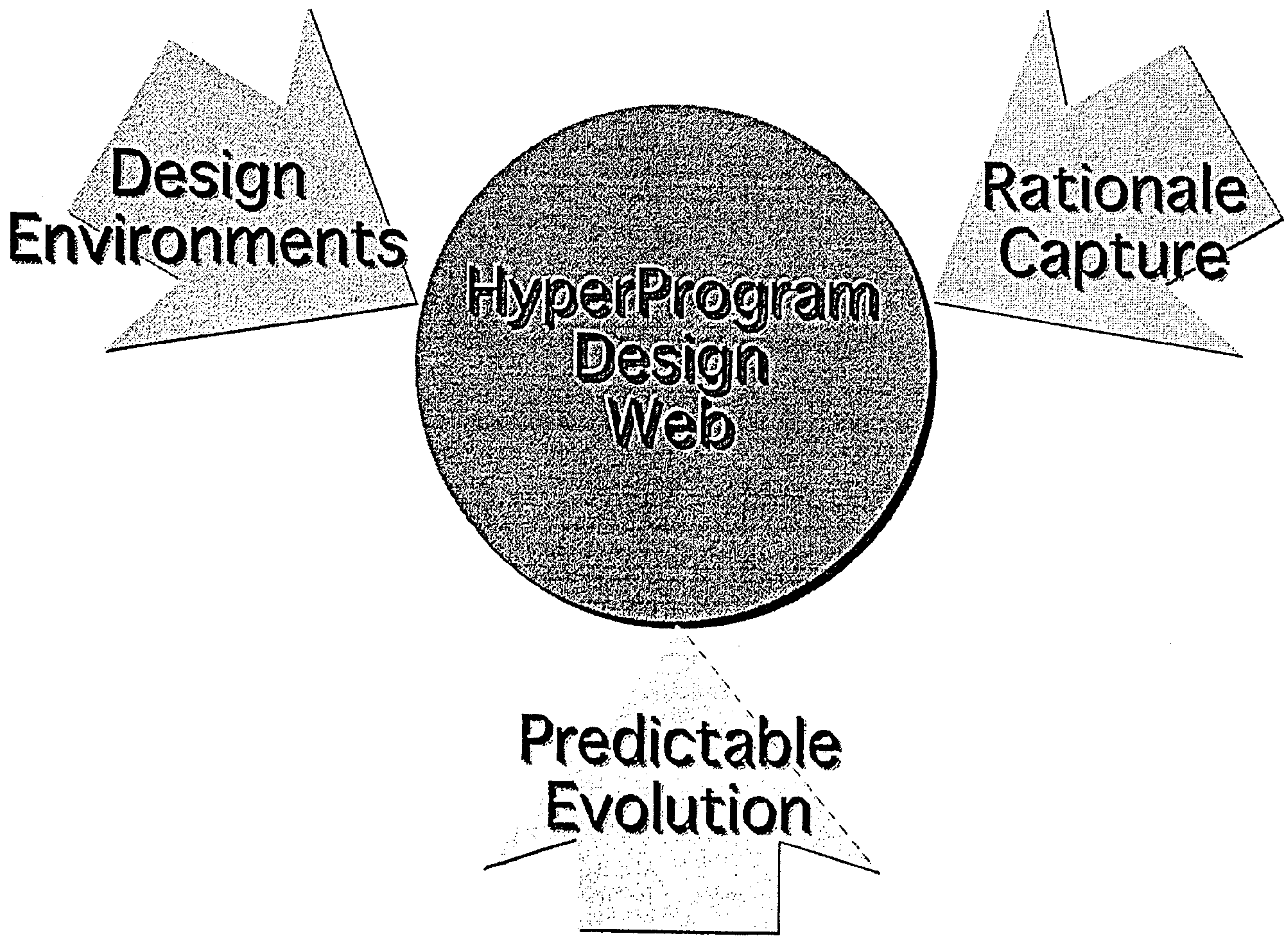
Core Capabilities for Evolution

- *Incrementality* : The ability to affect a change with effort proportional to the size of the change (not the size of the system).

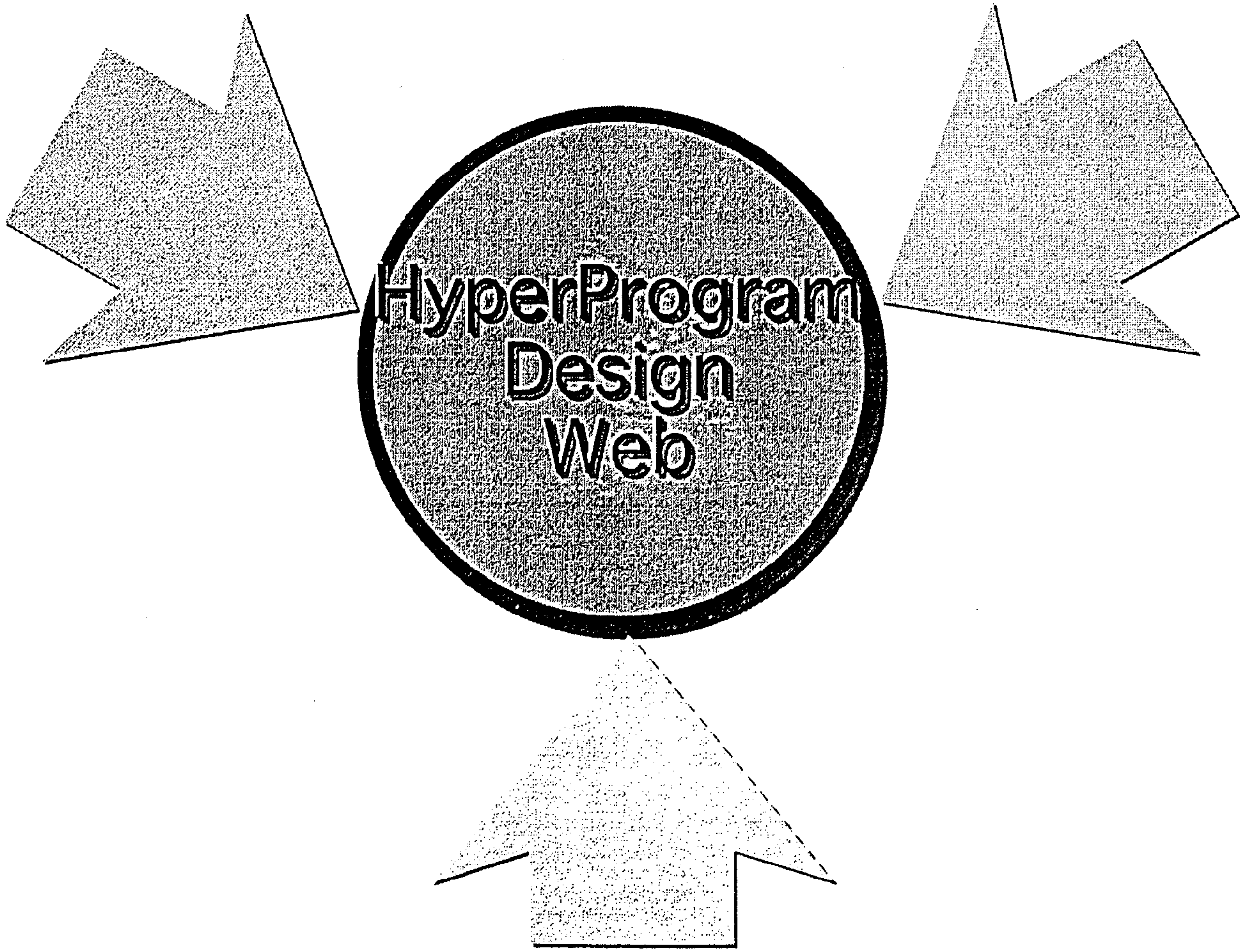
- *Information Accessibility* : The ability to capture and retrieve relevant information about the existing application family.

- *Predictability:* The ability to predict behavior, performance etc. of a new assembly of components.

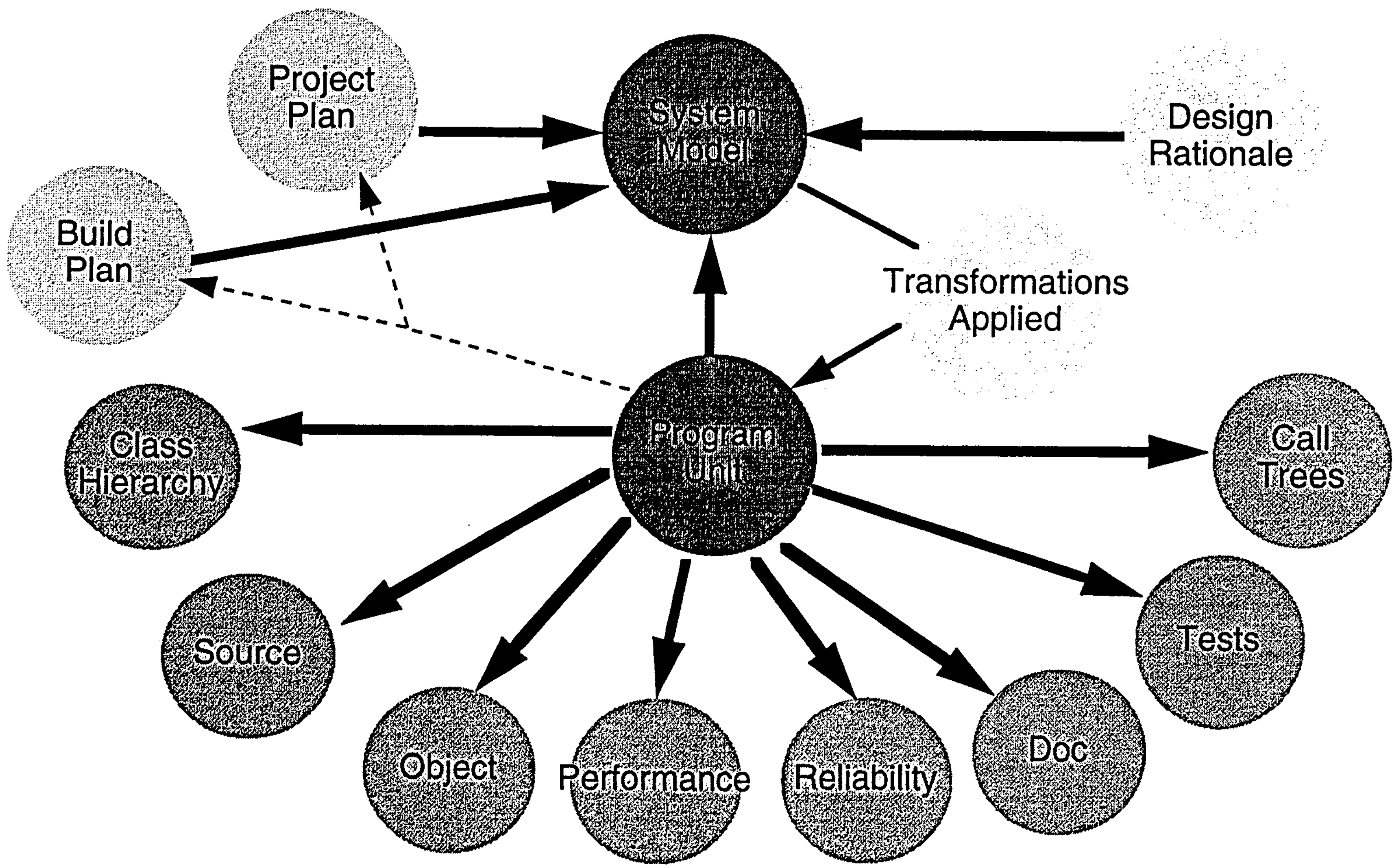
Technical Thrusts



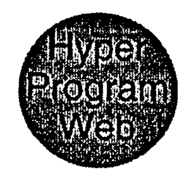
Technical Thrust 1: Evolutionary HyperProgram Design Webs



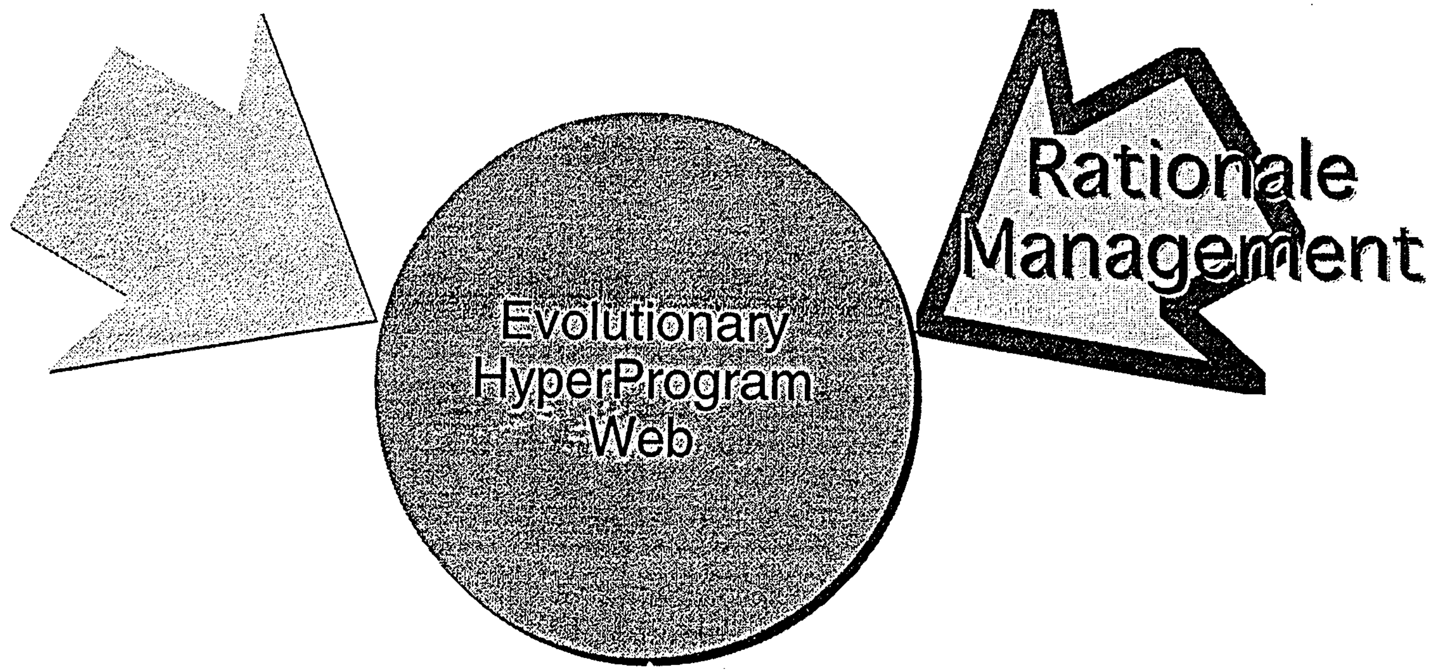
Hyper Program Design Webs



- **A Single Medium for All Aspects of Evolutionary Design**

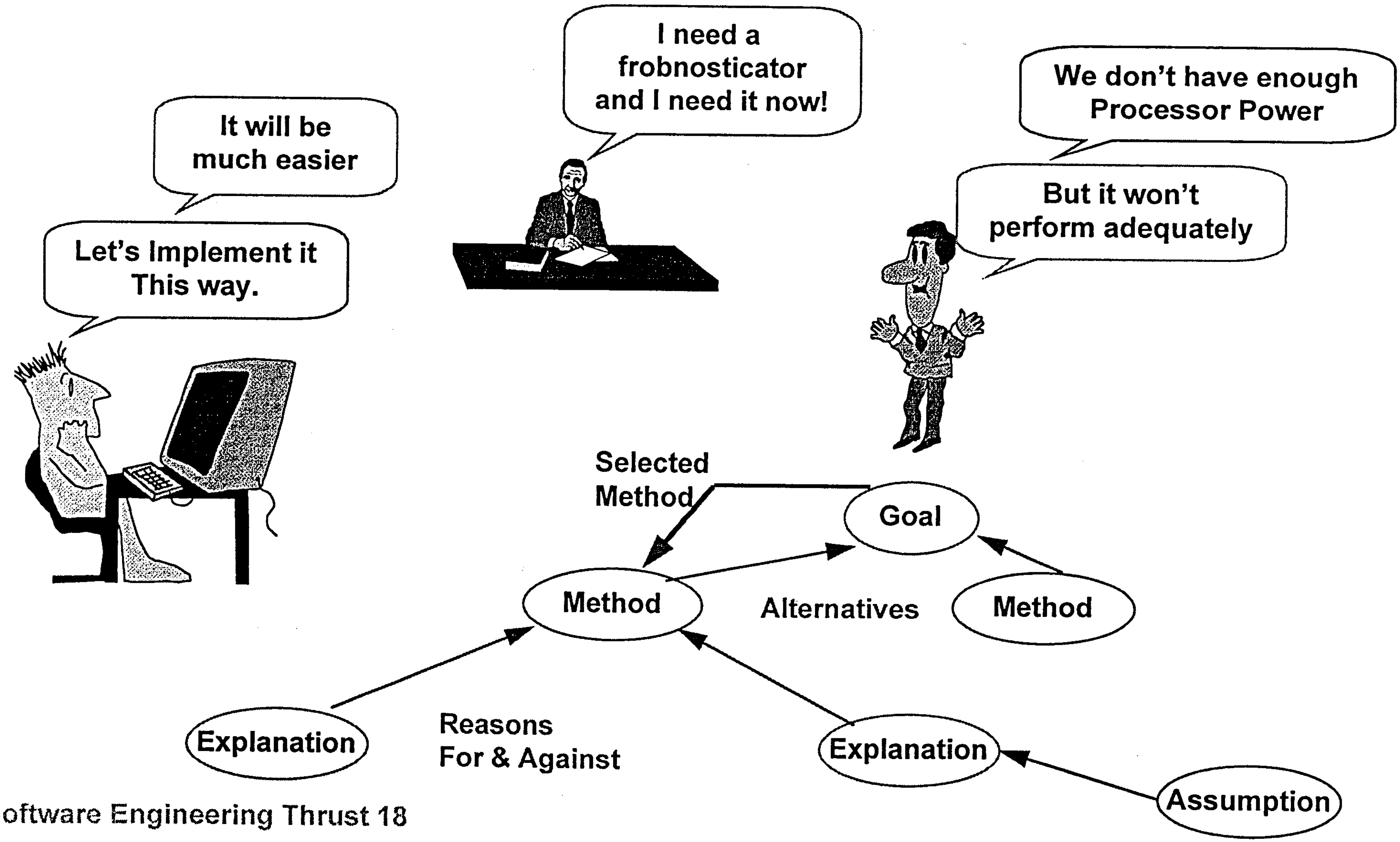


Technical Thrust 2: Rationale Management

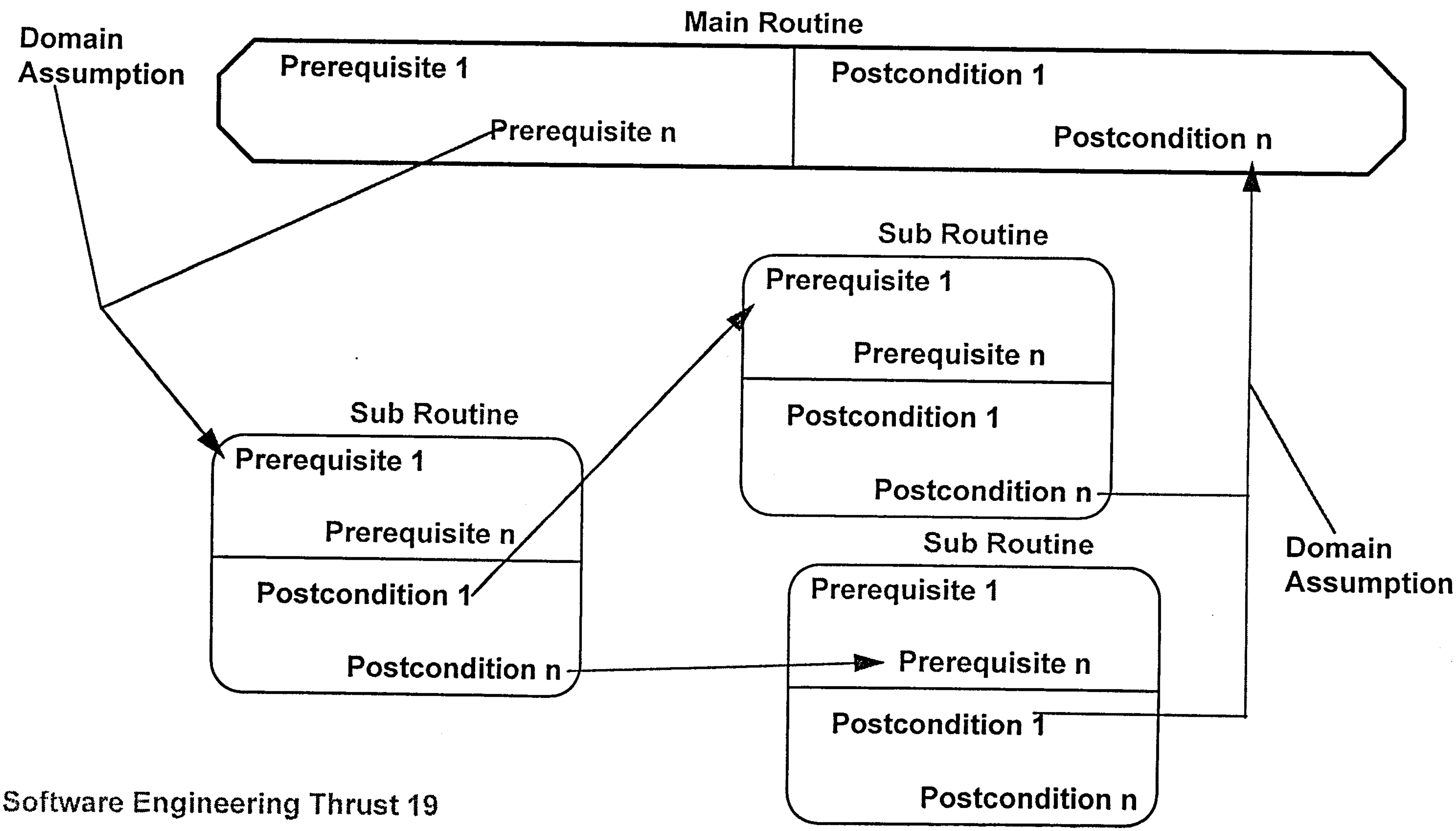


- Goal: To preserve correctness during system evolution
- Goal: To document for future reference the rationale for significant choices.

Rationale Capture: Design Deliberation



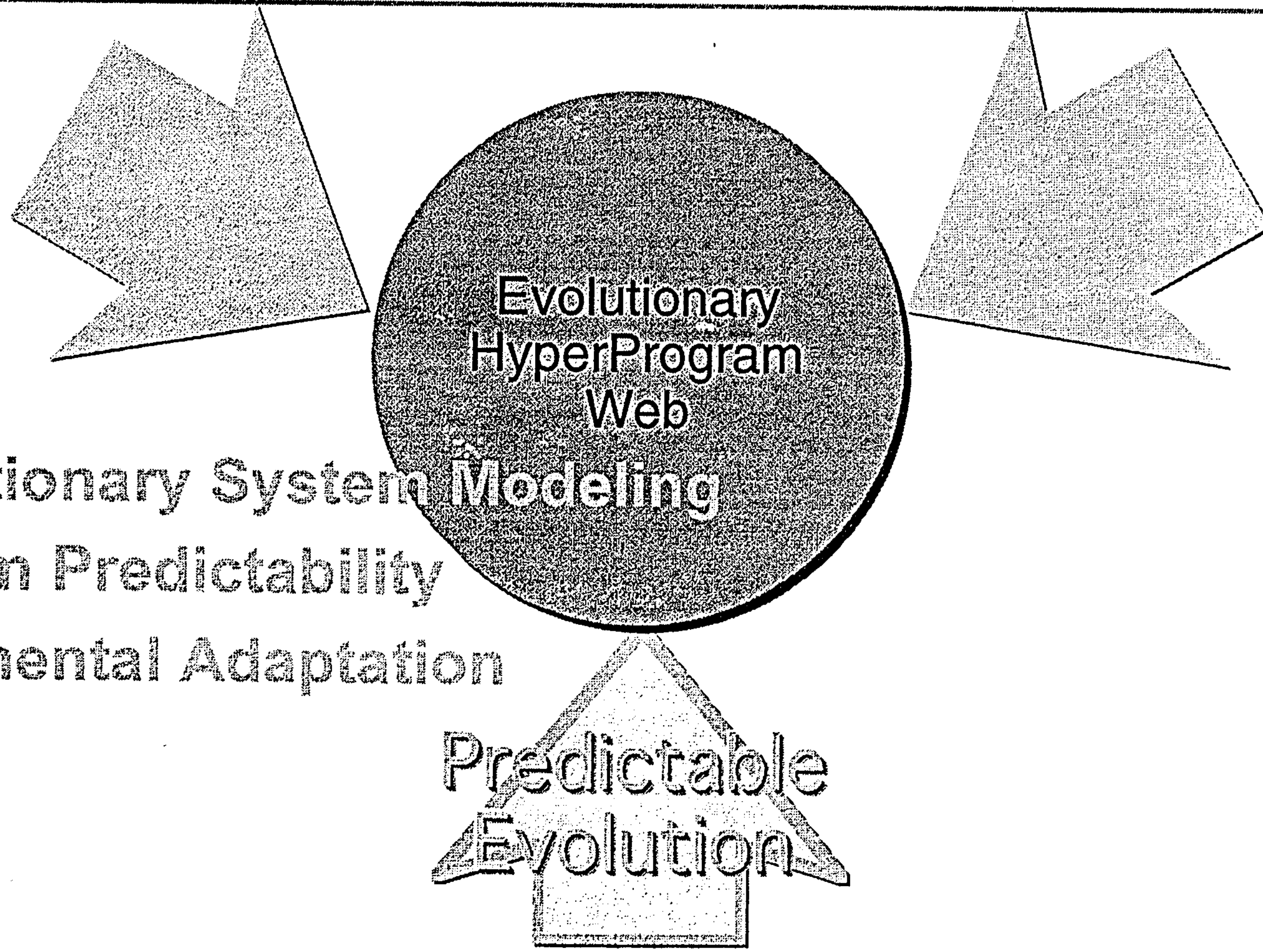
Rationale Capture: Dependency Management



Rationale Management: Key Ideas

- **Problems:**
  - Rationale is difficult to capture and is usually lost
  - Even when captured it provides little immediate benefit
- **Solutions**
  - Capture electronic discussions of system design and tradeoffs; store in HyperProgram Web.
  - Represent intermodule "purpose links" in HyperProgram Web.
  - Use natural language based matching techniques to find information.
- **Benefits:**
  - Avoid mistakes during evolution, preserve information for next generation

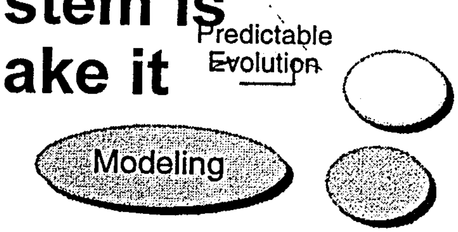
Technical Thrust 3: Predictable Architectural Evolution



- Evolutionary System Modeling
- System Predictability
- Incremental Adaptation

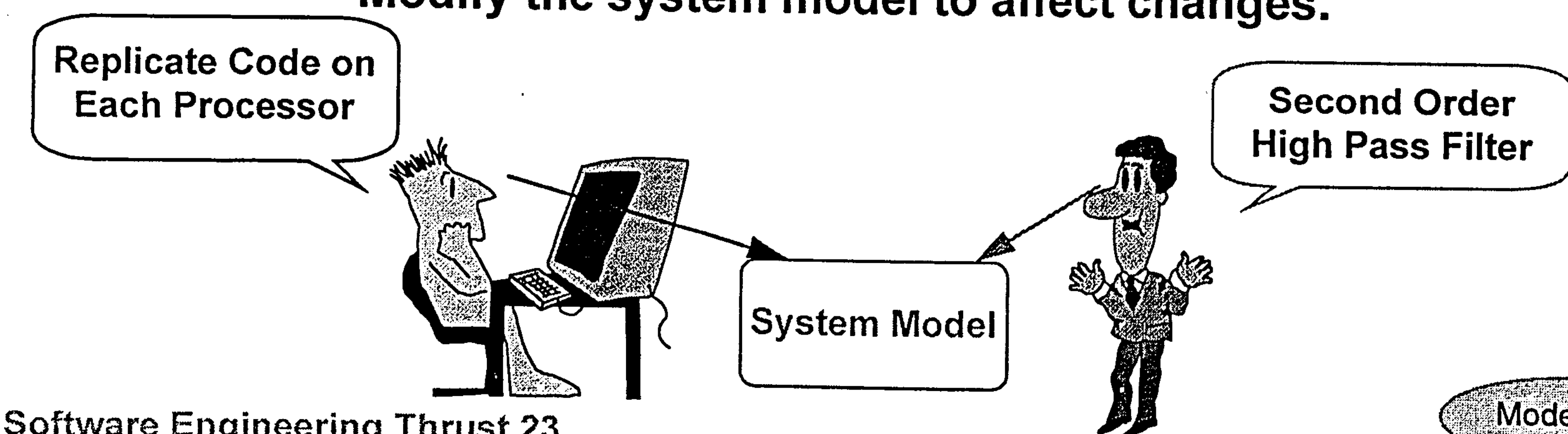
Clarity in the Presence of Distortion

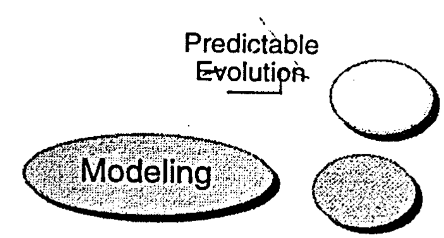
- "Before the Fall" there was clarity in the system design
- The Seven Deadly Sins:
  - High Performance
  - Real Time Requirements
  - Exceptional Conditions
  - Fault Tolerance
  - Security
  - Parallelism, Distributed Computation and Limited Bandwidth
  - Limited Memory
- To accomodate the Seven Sins, the system is modularized in peculiar ways which make it incomprehensible and non-evolvable.



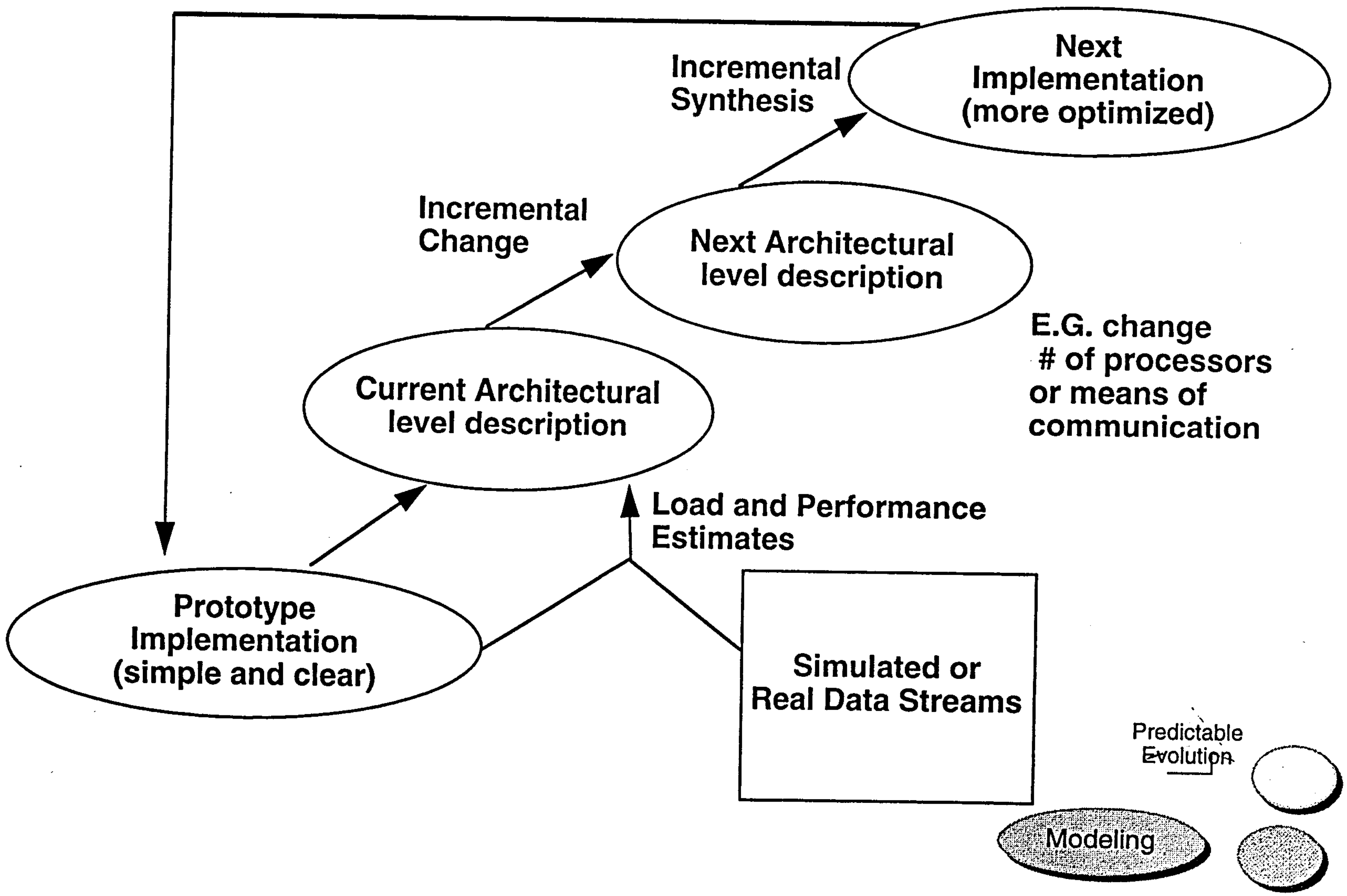
Evolutionary System Modeling

- **Goal: Maintain clarity of system in the presence of distorting factors.**
- **Approach:**
  - Model the System at the conceptual level using the language of the Application Engineer
  - Provide an interface for the software engineer to deal with the "7 deadly sins".
    - » Eventually automate this step
  - Synthesize the lower level code of the actual implementation
  - Modify the system model to affect changes.



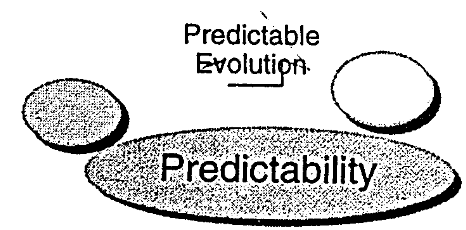


System Evolutionary Cycle



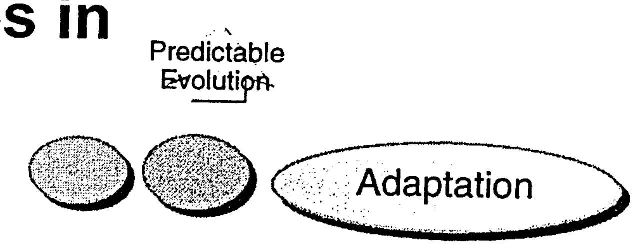
System Predictability

- **Problem: Testing and other Analyses consume 75% of the time in an upgrade cycle** (for high reliability systems).
- **Goal: Be able to estimate impact of architectural modifications with only incremental costs.**
- **Approach:**
  - Annotate system models in Web with test results and performance analyses.
  - Use Dependency Information to limit propagation of the change.
  - Reanalyze only changed components and those which depend on them.

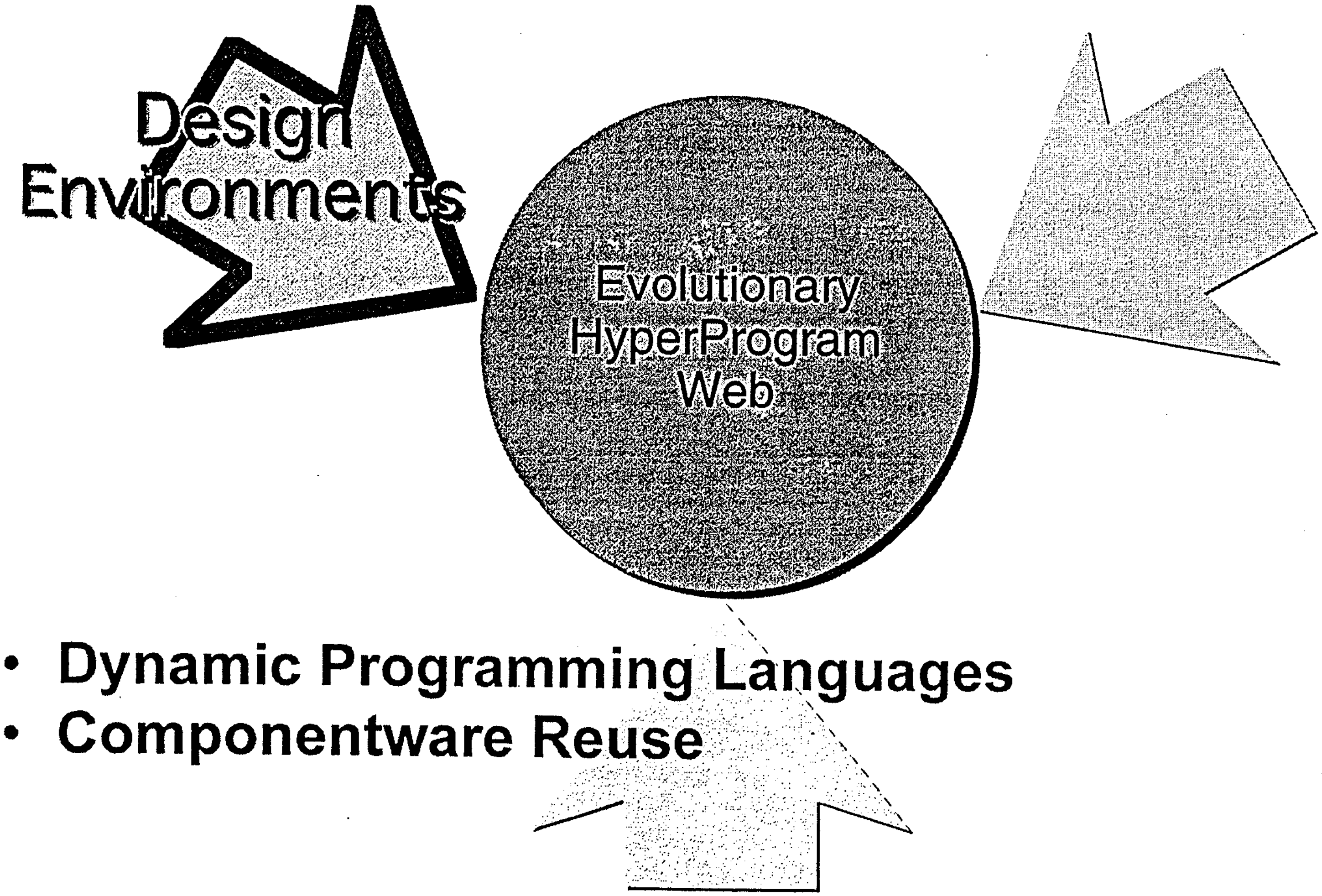


Incremental Adaptation

- Goal: Synthesize the new code implied by *incremental* changes to the system's architecture.
- Goal: Infer "conceptual design" structure of legacy system code by analysis of programs and text.
- Goal: Synthesize more efficient code based on metering of current system on real data.
- Benefits: Flexibility and Late Binding of Architectural Choices
- Record rationale for design choices in hypercode web.



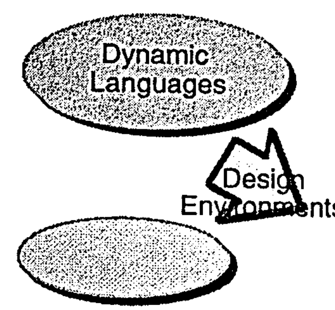
Technical Thrust 4: Evolutionary Design Environments



- Dynamic Programming Languages
- Componentware Reuse

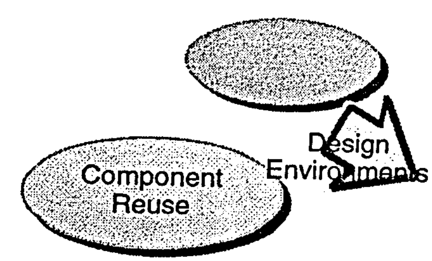
Dynamic Programming Languages

- Very High Level of Abstraction
  - Drawing on Lisp, Dylan,Smalltalk, Prolog, ML ...
- Incrementality and Late Binding:
  - dynamic type system, dynamic storage management, dynamic linking, dynamic extensibility.
  - Preserve flexibility until you know you don't need it.
  - Where flexibility is relinquished, Produce code as good as static languages.
- Highly extensible
  - Embed application specific languages within the base language.
  - Program Code and Architecture smoothly blend.
- Benefits: Ability to rapidly evolve and test system. Better Understand Architecture

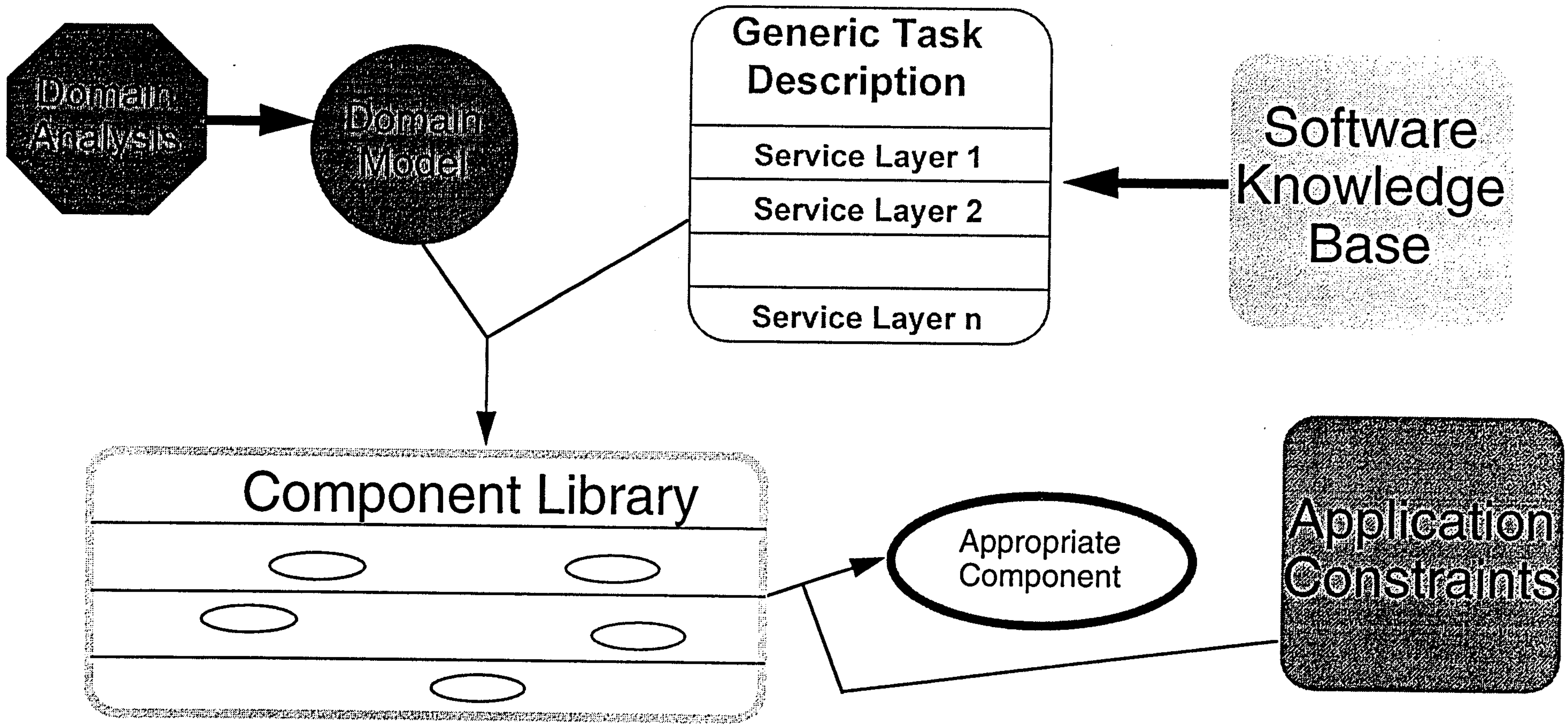


Componentware & Reuse

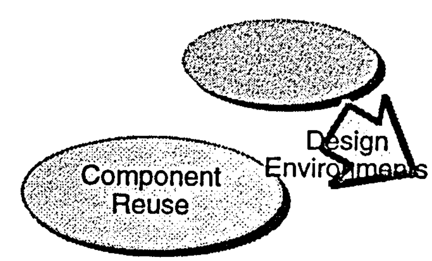
- **Goals:**
  - Within a specific domain, to reduce the amount of new code written.
  - To capitalize on commercial software components.
- **Problems:**
  - Finding a component which perform a function "near enough" to the desired one.
  - Modifying components to meet new needs and accommodate substantial variability without negative impact on existing clients.
- **Benefit:**
  - Substantial reduction in maintenance cost by keeping system modular and small



Reuse: Domain Analysis



- **Reuse depends on Domain Analysis**



Reuse: Object Oriented Protocols

- •Expose Interfaces of Main Services
- •Expose Conceptually Key Subroutines
- •Expose Subroutine Interfaces and their Calling Signatures
- •Expose Class Structure for Subroutine Dispatching